

UNIT 1 COGNITIVE PSYCHOLOGY

“Mind and world ... have evolved together, and in consequence are something of a mutual fit”.

– William James

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1.0 INTRODUCTION

Cognitive psychology is the study of mental processes such as perceiving, remembering, and reasoning. Why do psychologists study mental processes? Since the beginning of recorded history, people have expressed curiosity about the operation of the mind, largely because they believed that behaviour is the result of mental processes. For example, how are we to understand the very behaviour in which you are engaged at this moment, reading this course book? At one level, we are interested in explaining your ability to comprehend what you are reading, and in so doing, we are likely to appeal to processes of perception of words and computation of meaning. At another level, we might explain your motivation for reading in terms of your goal to complete this course, which in turn is motivated by your goal of obtaining a degree in order to follow some plan that you have for a career. The point is that your behaviour of reading this book is determined in part by your intent to meet some goal and fulfill some plan. Intentionality, goals, and plans are mental phenomena that affect behaviour. Further, the specific behaviour, in this case, reading, is understood by appeal to the specific mental processes involved in perception and comprehension of text. In short, the study of mental processes is important because these processes are responsible for much of our behaviours. In this unit you will be studying the definition and description of cognitive psychology, distinctive research methods, domains of cognitive psychology, metaphor of cognition etc.

1.1 OBJECTIVES

After reading this unit, you will be able to:

- Field of cognitive psychology;
- Provide a foundation on which to build an understanding of the topics in cognitive psychology;
- Describes some of the intellectual history of the study of human thinking; and
- Emphasises some of the issues and concerns that arise when we think about how people think.

1.2 COGNITIVE PSYCHOLOGY: AN INTRODUCTION

Cognitive psychology is the study of how people perceive, learn, remember, and think about information. A cognitive psychologist might study how people perceive various shapes, why they remember some facts but forget others, or how they learn language. Consider some examples of everyday experiences that are also of theoretical interest to cognitive psychologists:

How many times have you carefully proofread written work, only to be embarrassed later by an obvious error you overlooked?

Many times what we see is determined as much by the context in which it occurs as by what is actually there, an issue of pattern recognition.

Have you noticed the difficulty of simultaneously taking notes in class and understanding a lecture?

Explanations of this kind of difficulties are found in the discussion of attention.

When you dial the telephone directory assistance for a telephone number and do not have a pen to note it down, why do you have to repeat the number until you have dialed it? And why you have to make your call again to enquire the number if someone talks to you before you dial the number?

These are problems associated with the short term memory.

Do you remember the experience of working on a problem or a puzzle that you were unable to solve, but after taking a break from the problem, you subsequently obtained a solution?

This phenomenon, known as incubation effect, along with other commonly experienced events is an aspect of problem solving.

Why do objects look farther away on foggy days than they really are? This discrepancy of perception can be dangerous, even deceiving drivers into having accidents.

These are just a few of the many examples of everyday experiences which are discussed and explored by the experiments and theory of cognitive psychology.

Two points about these examples should be considered as we attempt to gain an overview of cognitive psychology.

- 1) All represent instances of difficulty or failure of mental processes. We rarely think of them unless they fail to work. Failure of mental processes are immediately noticed because they can be frustrating, embarrassing, and sometimes even dangerous and, consequently, such failures become useful tools for the psychological analysis of mental phenomena.
- 2) Cognitive psychology is interested in what is generally called mental phenomena. In this sense, the examples just discussed are consistent with the dictionary definition of cognitive psychology: “the scientific study of the mind”.

While it is hoped that examples help clarify the definition, questions undoubtedly remain concerning how one goes about this ‘scientific study of mind’. To address these questions, here’s a brief discussion of the scientific methods, followed by an extensive description of the important historical events leading up to modern cognitive psychology.

Next is a brief overview of the major methods, issues, and content areas of cognitive psychology.

1.3 RESEARCH METHODS IN COGNITIVE PSYCHOLOGY

This consists of the various research methods that we use in cognitive psychology. Every research has a goal and it is achieved through appropriate methodology. Let us see what are the goals of research.

1.3.1 Goals of Research

To better understand the specific methods used by cognitive psychologists, one must grasp the goals of research in cognitive psychology. Briefly, those goals include data gathering, data analysis, theory development, hypothesis formulation, hypothesis testing, and perhaps even application to settings outside the research environment. However, most cognitive psychologists want to understand more than cognition. They also seek to understand the *how* and the *why* of thinking. That is, researchers seek ways to explain cognition as well as describe it. To move beyond descriptions, cognitive psychologists must leap from what is observed directly to what can be inferred regarding observations.

1.3.2 Distinctive Research Methods

Cognitive psychologists use various methods to explore how humans think. These methods include (i) laboratory or other controlled experiments, (ii) psychobiological research, (iii) self-reports, case studies, naturalistic observation, and (iv) computer simulations and artificial intelligence. Each method offers distinctive advantages and disadvantages.

- i) **Experiments on Human Behaviour:** In controlled experimental designs, an experimenter conducts research, typically in a laboratory setting. The experimenter controls as many aspects of the experimental situation as possible. There are basically two kinds of variables in any given experiment – *independent variables* and *dependent variables*. The irrelevant variables are held constant and are called control variables. In implementing

experimental method, the experimenter must use a representative and random sample of the population of interest. S/he must also exert rigorous control over the experimental conditions. If those requisites for the experimental method are fulfilled, the experimenter may be able to infer probable causality. This influence is of the effects of the independent variable (the treatment) on the dependent variable (the outcome) for the given population.

- ii) ***Psychobiological Research:*** Through *psychobiological research*, investigators study the relationship between cognitive performance and cerebral events and situations. The various specific techniques used in the psychobiological research generally fall into three categories. The first category is that of techniques for studying an individual's brain *post-mortem*, relating the individual's cognitive function prior to death to observable features of the brain. The second category is techniques for studying images showing structures of or activities in the brain of an individual who is known to have a particular cognitive deficit. The third is techniques for obtaining information about cerebral processes during the normal performance of a cognitive activity (e.g. by using brain imaging techniques).
- iii) ***Self-Reports, Case Studies, and Naturalistic Observation:*** Individual experiments and psychobiological studies often focus on precise specification of discrete aspects of cognition across individuals. To obtain richly textured information about how particular individuals think in a broad range of contexts, researchers may use *self-reports* (an individual's own account of cognitive processes), *case studies* (in-depth studies of individuals), and *naturalistic observation* (detailed studies of cognitive performance in everyday situations and not laboratory contexts). On the one hand, experimental research is most useful for testing hypotheses. On the other hand, research based on qualitative methods is often particularly useful for the formulation of hypotheses. These methods are also useful to generate descriptions of rare events or processes that we have no other way to measure.
- iv) ***Computer Simulations and Artificial Intelligence:*** Digital computers played a fundamental role in the emergence of the study of cognitive psychology. One kind of influence is indirect through models of human cognition based on models of how computers process information. Another kind is direct, that is through computer simulations and artificial intelligence. In computer simulations, researchers program computers to imitate a given human function or process. Some researchers even have attempted to create computer models of the entire cognitive architecture of the human mind. Their models have stimulated heated discussions regarding how the human mind may function as a whole. Sometimes the distinction between simulation and artificial intelligence is blurred. It is also possible to combine the two approaches.

Cognitive psychologists often broaden and deepen their understanding of cognition through research in cognitive science. Cognitive science is a cross-disciplinary field that uses ideas and methods from cognitive psychology, psychobiology, artificial intelligence, philosophy, linguistics, and anthropology. Cognitive psychologists use these ideas and methods to focus on the study of

how humans acquire and use knowledge. They also work in collaboration with other psychologists, such as social psychologists (in the field of social cognition), psychologists who study motivation and emotion, and engineering psychologists (who study human-machine interactions).

1.4 DOMAINS OF COGNITIVE PSYCHOLOGY

Modern cognitive psychology freely, draws theories and techniques; from twelve principal areas of research (see Figure 1.1). Each area, in brief, is described below:

- i) **Cognitive Neuroscience:** Only within the past few years have cognitive psychologists and cognitive neuroscientists formed a close working relationship. Thus far, this union has produced some of the most provocative developments in the study of our mental character. Cognitive psychologists are seeking neurological explanations for their findings, and neuroscientists are turning to cognitive psychologists to explain observations made in their laboratories. Every part of the cognitive process from sensation to memory is supported by basic electrochemical processes taking place in the brain and nervous system.

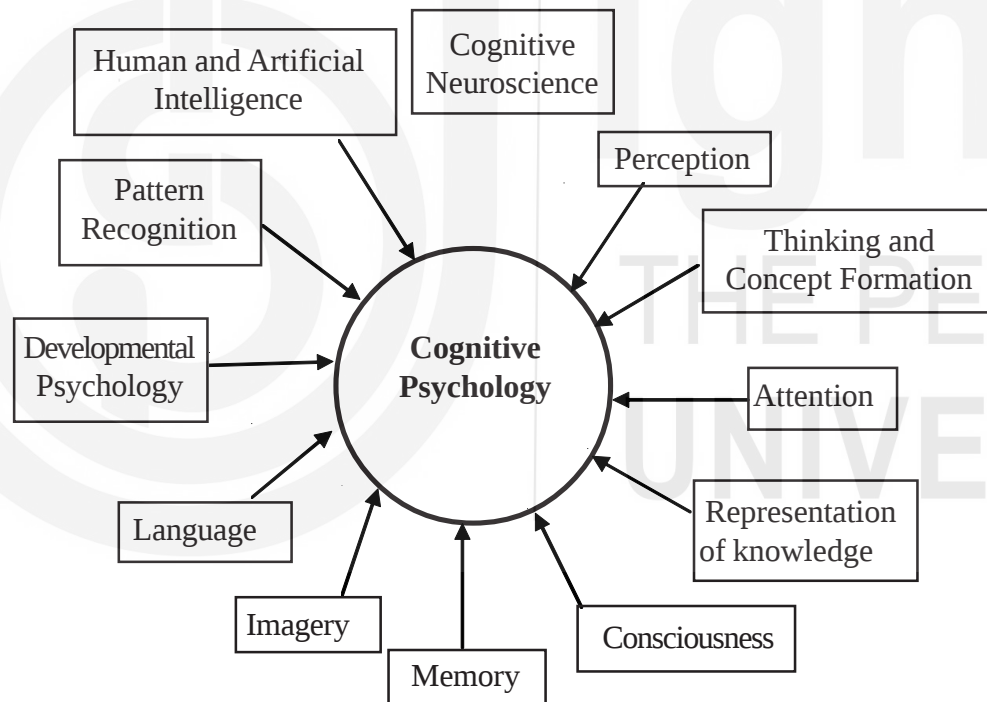


Fig. 1.1: Principal research areas of cognitive psychology

- ii) **Perception:** The branch of psychology directly involved with the detection and interpretation of sensory stimuli is perception. From experiments in perception, we have a good understanding of the sensitivity of the human organism to sensory signals and more important to cognitive psychology of the way we interpret sensory signals. The experimental study of perception has helped identify many of the parts of this process. However, the study of perception alone does not adequately account for the expected performance; other cognitive systems are involved, including pattern recognition, attention, consciousness, and memory.

- iii) **Pattern Recognition:** Environmental stimuli rarely are perceived as single sensory events; they usually are perceived as part of a more meaningful pattern. The things we sense – see, hear, feel, taste, or smell—are almost always part of a complex pattern of sensory stimuli. Think about the problem of reading. Reading is a complex effort in which the reader is required to form a meaningful pattern from an otherwise meaningless array of lines and curves. By organising the stimuli that make up letters and words, the reader may then access meaning from his or her memory. The entire process takes place in a fraction of a second, and considering all the neuroanatomical and cognitive systems involved, this feat – performed daily by all sorts of people – is wondrous.
- iv) **Attention:** Although we are information-gathering creatures, it is evident that under normal circumstances we are also highly selective in the amount and type of information to which we attend. Our capacity to process information seems to be limited to two levels – sensory and cognitive. If too many sensory clues are imposed upon us at any given time, we can become overloaded; if we try to process too many events in memory, we can become overloaded, which may cause a breakdown in performance. All of us have felt the same way at one time or another.
- v) **Consciousness:** Consciousness is defined as “the current awareness, of external or internal circumstances.” Rejected as being “unscientific” by the behaviourists, the word *consciousness* and the concept it represents simply did not fade away. For most people, consciousness and unconscious thoughts (such as you might have on a first date) are very real. For example, when you glance at your watch while studying and it reads “10:42 (P.M.),” you are conscious, or, aware, of that external signal. However, your reading of the time also brings up another conscious thought, one that was initially activated by reading the time but is from “inside.” That conscious thought might be, “It’s getting late: I’d better finish this chapter and go to bed”. Consciousness has gained new respectability recently and now is a concept studied seriously in modern cognitive psychology.
- vi) **Memory:** Memory and perception work together. The information available to us comes from our perception, short-term memory, and long-term memory. Most obvious long-term storage is the knowledge of the language. We draw words from LTM and more or less use them correctly. In a fleeting second, we are able to recall information about an event of years before. Such information does not come from an immediate perceptual experience; it is stored along with a vast number of other facts in the LTM.
- vii) **Representation of Knowledge:** Fundamental of all human cognition is the representation of knowledge: how information is symbolised and combined with the things stored in the brain. This part of cognition has two aspects: the conceptual representation of knowledge in mind and the way the brain stores and process information. The conceptual representation in different individuals can be considerably different. In spite of these inherent dissimilarities between representations of knowledge, most humans do experience and depict experience in similar enough ways to get along well in the world. The content of this information is also hugely different. But our neurological web entraps information and experiences and holds them in structures that are similar in all human brains.

- viii) **Imagery:** Cognitive psychologists are especially interested in the topic of internal representations of knowledge. The mental images of the environment are formed in the form of a *cognitive map*, a type of internal representation of the juxtaposed buildings, streets, street signs, spotlights, and so on. From the cognitive maps, we are able to draw out significant cues. Although the experimental study of mental imagery is relatively new to psychology, some significant research has recently been reported.
- ix) **Language:** One form of knowledge shared by all human societies is the knowledge of language. Language is the principal means by which we acquire and express knowledge; thus, the study of how language is used is a central concern of cognitive psychology. Human language development represents a unique kind of abstraction, which is basic to cognition. Language processing is an important component of information processing and storage. Language also influences perception, a fundamental aspect of cognition.
- x) **Developmental Psychology:** Developmental psychology is another important area of cognitive psychology that has been intensely studied. Recent studies and theories in developmental cognitive psychology have greatly expanded our understanding of how cognitive structures develop. As adults, we have all lived through childhood and adolescence and we share maturational experiences with all members of our species.
- xi) **Thinking and Concept Formation:** Thinking is the crown jewel of cognition. Thinking is the process by which a new mental representation is formed through the transformation of information. Advances in cognitive psychology have led to a formidable arsenal of research techniques and theoretical models. An ability to think and form concepts is an important aspect of cognition. Similar concepts help in the understanding and processing of information. There is a considerable body of knowledge about the laws and processes of concept formation.
- xii) **Human and Artificial Intelligence:** Human intelligence includes the ability to acquire, recall, and use knowledge to understand concrete and abstract concepts and the relationships among objects and ideas, to understand a language, to follow instructions, to convert verbal descriptions into actions, and to behave according to the rules, and to use knowledge in a meaningful way.

The specialty within the computer science called artificial intelligence has had a major influence on the development of cognitive science, especially since the design of programs requires knowledge of how we process information. Cognitive psychology also addresses to find out whether a perfect robot can simulate human behaviour.

1.5 A BRIEF HISTORY OF COGNITIVE PSYCHOLOGY

As we have learned, a great portion of cognitive psychology deals with how knowledge is represented in the mind. In this section on the history of cognitive psychology we will review three major periods (for a detailed history see Solso & MacLin, 2000; Wilson & Keil, 1999). First, we will deal with traditional ideas

from a very early period. Then we touch on the way knowledge and thinking was conceptualised by Renaissance scholars. Finally, we will deal with the modern period with emphasis on current ideas and methods.

1.5.1 Early Thoughts on Thinking

Where did knowledge come from, and how is it represented in the mind? That eternal question is fundamental to cognitive psychology as it has been through the ages of humankind. Basically, two answers have been proposed. The *empiricists* maintain that knowledge comes from experience, and the *nativists* suggest that knowledge is based on innate characteristics of the brain. From a scientific perspective, neither case can be definitively proved, so the argument continues without clear resolution. With these issues clearly before us, let's consider the way ancient philosophers and early psychologists grappled with the issue. The fascination with knowledge can be traced to the earliest writings. Early theories were concerned with the seat of thought and memory. Ancient Egyptian hieroglyphics suggest their authors believed that knowledge was localised in the heart—a view shared by the early Greek philosopher Aristotle but not by Plato, who held that the brain was the locus of knowledge.

1.5.2 Cognition in the Renaissance and Beyond

Renaissance philosophers and theologians seemed generally satisfied that knowledge was located in the brain. They considered that knowledge was acquired not only through the physical senses (*mundus sensibilis* – touch, taste, smell, vision, and hearing) but also from divine sources (*mundus intellectualis*—*Deus*).

During the eighteenth century, when philosophic psychology was brought to the point where , scientific psychology could assume a role, the British empiricists, George Berkeley, David Hume, and, later, James Mill and his son John Stuart Mill suggested that internal representation is of three types: (1) direct sensory events, (2) faint copies of percepts, or those that are stored in memory; and (3) transformation of these faint copies, as in associated thought. These notions are the basis of much current research in cognitive psychology.

During the nineteenth century, the early psychologists like Gustav Fechner, Franz Brentano, Hermann Helmholtz, Wilhelm Wundt, G; E. Muller, Oswald Kulpe, Hermann Ebbinghaus, Sir Francis Galton, Edward Titchener, and William James and others started to break away from philosophy to form a discipline based on empirical results rather than on speculation. By the last half of the nineteenth century, theories of the representation of knowledge were clearly dichotomous: that emphasised the structure of mental representation (Wundt, Titchner); and the processes or acts (Brentano).

About the same time in America, James critically analysed the new psychology that was developing in Germany. He established the first' psychological laboratory in America, wrote the definitive work in psychology in 1890 (*Principles of Psychology*), and developed a well-reasoned model of the mind. Perhaps James's most direct link with modern cognitive psychology is in his view of memory, in which both structure and process play an important role. F. C. Donders and James Cattell, contemporaries of James's, performed experiments using the perception of brief visual displays as a means of determining the time required for mental operations. The technique, subject matter, procedures, and even the interpretation

of results of these early scientists seem to have anticipated the emergence of the cognitive psychology a half-century later.

1.5.3 Cognitive Psychology in Early Twentieth Century

The representation of knowledge took a radical turn with the advent of twentieth-century behaviourism and Gestalt psychology. The behaviourist views of human and animal psychology were cast in a framework of stimulus-response (S-R) psychology, and Gestalt theorists built elaborate conceptualisations of internal representation within the context of isomorphism – one-to-one relationship between representation and reality.

Psychological studies of mental processes as conceptualised in the late nineteenth century suddenly became unfashionable, displaced by behaviourism. Studies of internal mental operations and structures such as attention, consciousness, memory, and thinking were laid to rest and remained so for about fifty years. To the behaviourists, internal states were subsumed under the label of “intervening variable,” that mediated the effects of stimuli on responses and were neglected in favor of making observations on behaviour rather than on the mental processes.

In 1932, some years before the cognitive revolution swept across psychology, learning psychologist Edward Tolman from the University of California at Berkeley published *Purposive Behavior in Animals and Men*. In this seminal work, Tolman observed that what rats learn in a maze is the layout of the land rather than simply a series of S-R connections. The animal, according to Tolman’s interpretation, gradually developed a “picture” of his environment that was later used to find the goal. This picture was called a cognitive map. Tolman’s postulate about cognitive maps in animals did anticipate the contemporary preoccupation with how knowledge is represented in a cognitive structure.

Also in 1932 Sir Frederick Bartlett from Cambridge University wrote *Remembering* in which he rejected the then popular view that memory and forgetting can be studied by means of nonsense syllables, as had been advocated by Ebbinghaus in Germany during the previous century. In the study of human memory, Bartlett argued, the use of rich and meaningful material under naturalistic conditions would yield far more significant conclusions. Bartlett introduced the concept of schema as a unifying theme that describes the essence of an experience. Schema theory plays a central role in modern theories of memory. The fecund ideas of Tolman in America and Bartlett in England highly influenced the thinking of future cognitive psychologists.

1.5.4 Cognitive Psychology—As it is Today

In the 1950s interest again began to focus on attention, memory, pattern recognition, images, semantic organisation, language processes, thinking, and even consciousness (the most dogmatically eschewed concept), as well as other “cognitive” topics once considered outside the boundary of experimental psychology (vis-à-vis. behaviourism). New journals and professional groups were founded as psychologists began more and more to turn to cognitive psychology. As cognitive psychology became established with even greater clarity, it was plain that this was a brand of psychology different from that in vogue during the 1930s and 1940s. Among the most important forces accounting for this neocognitive revolution were the following:

The “failure” of behaviourism. Behaviorism, which generally studied overt responses to stimuli, failed to account for the diversity of human behaviour as in the case of language. Furthermore, there were some topics ignored by the behaviourists that seemed to be profoundly related to human psychology. These included memory, attention, consciousness, thinking, and imagery. It was apparent that internal mental processes were very real parts of psychology and required investigation.

The emergence of communication theory. Communication theory prompted experiments in signal detection, attention, cybernetics, and information theory – areas of significance to cognitive psychology.

Modern linguistics. New ways of viewing language and grammatical structure became incorporated into attitudes concerning cognitions.

Memory research. Research in verbal learning and semantic organisation provided a sturdy empirical base for theories of memory, which led to the development of models of memory systems and the appearance of testable models of other cognitive processes.

Computer science and other technological advances. Computer science, and especially a subdivision of it—artificial intelligence—caused reexamination of basic postulates of problem solving and memory processing and storage, as well as of ‘language processing and acquisition. Research capabilities were greatly expanded by new experimental devices.

Cognitive development. Psychologists interested in development psychology discovered an orderly unfolding of abilities with maturation. Notable among developmental psychologists during this period was Jean Piaget, who described how children develop an appreciation for concepts from infancy to adolescence. Such progress of abilities seems to be natural.

From the earliest concepts of representational knowledge to recent research, knowledge has been thought to rely heavily on sensory inputs. That theme runs from the Greek philosophers, through Renaissance scholars, to contemporary cognitive psychologists. But are internal representations of the world identical to the physical properties of the world? Evidence is increasing that many internal representations of reality are not the same as the external reality—that is, they are not isomorphic. Tolman’s work with laboratory animals and Bartlett’s work with human subjects suggest that information from the senses is stored as an abstract representation. Furthermore, studies of neurology clearly show that information from the outside world is sensed and stored as in a neurochemical code.

1.6 KEY ISSUES IN THE STUDY OF COGNITIVE PSYCHOLOGY

If the important ideas are reviewed, it is observed that some major themes underlie all of cognitive psychology. Some of these issues are discussed dialectically here:

Nature versus Nurture – Which is more influential in human cognition – nature or nurture? If we believe that innate characteristics of human cognition are more

important, we might focus our research on studying innate characteristics of cognition. If we believe that the environment plays an important role in cognition, we might conduct research exploring how distinctive characteristics of environment seem to influence cognition.

Rationalism versus Empiricism – How should we discover the truth about ourselves and about the world around us? Should we do so by trying to reason logically, based on what we already know? Or should we do so by observing and testing our observations of what we can perceive through our senses? And how can we combine theory with empirical methods to learn the most we can about cognitive phenomena?

Structures versus Processes - Should we study the structures (contents, attributes, and products) of the human mind? Or should we focus on processes of human thinking?

Domain generality versus Domain specificity – Are the processes we observe limited to single domains, or are they general across a variety of domains? Do observations in one domain apply also to all domains, or do they apply only to specific domains observed?

Validity of causal inferences versus Ecological validity – Should we study cognition by using highly controlled experiments that increase the probability of valid inferences regarding causality? Or should we use more naturalistic techniques?

Applied versus Basic research – Should we conduct research into fundamental cognitive processes? Or should we study ways in which to help people use cognition effectively in practical situations?

Biological versus Behavioural methods – Should we study the brain and its functions directly, perhaps even scanning the brain while people are performing cognitive tasks? Or should we study people's behaviour in cognitive tasks, looking at measures such as percentage correct and reaction time?

Note that these questions can be posed in the “either/or” form of thesis/antithesis, or in the both/and form of a synthesis of views or methods, which often proves more useful than one extreme position or another.

1.7 KEY IDEAS IN COGNITIVE PSYCHOLOGY

Certain key ideas seem to keep emerging in cognitive psychology, regardless of the particular phenomenon one studies. Here are what might be considered the five major ideas:

Data in cognitive psychology can be fully understood only in the context of an explanatory theory, but theories are empty without empirical data.

Cognition is generally adaptive but not in all specific instances.

Cognitive processes interact with each other and with noncognitive processes.

Cognition needs to be studied through a variety of scientific methods.

All basic research in cognitive psychology may lead to applications, and all applied research may lead to basic understandings.

Activity: Think about some of the fields of cognitive psychology to which these key themes and issues may apply.

1.7.1 Computer Metaphor and Human Cognition

Although Pascal, Descartes, and others dreamt of computing machines centuries ago, it was not until the development of high-speed digital computers more than fifty years ago that practical machines were invented. These machines gained enormous acceptance and are presently used in virtually every aspect of modern life. Originally, such devices were thought to be wonderful number crunchers capable of performing a multitude of complex mathematical operations in a fraction of the time required by humans. However, it was quickly discovered that they could perform functions that resembled human problem solving.

However, what computers do well (perform high-speed mathematical functions and abide by rule-governed logic) humans do poorly, relatively speaking. And what humans do well (form generalisations, make inferences, understand complex patterns, and have emotions) computers do poorly, or not at all. Despite this problem, a second generation of cognitive-computer scientists is working toward building computers that looked something like a brain.

These new computers are sometimes called neural networks and act more like humans than the earlier versions. They are able to make generalisations and understand complex visual patterns, are slow at math, and make witless mistakes. Although they still do not have emotions, they are nevertheless a mark of success. We now know that there are fundamental differences between the internal workings of computers and the internal workings of the brain. Nevertheless, the computer metaphor continues to have a profound and generally positive impact on the development of cognitive psychology.

1.7.2 Cognitive Science

Three powerful areas of scientific development, namely, computer science, neuroscience, and cognitive psychology, converge to create a new science called cognitive science. The boundaries between these disciplines are sometimes hard to distinguish, that is, some cognitive psychologists may be closer to neuroscience, others to computer science. One thing is clear, that is the science of human cognition is undergoing a radical transformation as a result of major changes in computer technology and brain science. Cognitive psychology makes full use of recent discoveries in neuroscience and computer science that illuminate the cognitive properties of the human species.

1.7.3 Neuroscience and Cognitive Psychology

During the early stages of cognitive psychology, little attention was given to physiological psychology or neuroanatomy. Much of the early information on the brain and its functions resulted from head traumas incurred during wars and accidents. The central issue neurologists struggled with was whether the brain was a holistic organ, with operations distributed throughout its infrastructure, or whether activities were localised and tied to specific regions. For example, did learning a specific act take place in a localised area of the brain, or was learning distributed throughout many parts of the brain? Among the most prominent of the scientists who wrestled with these issues was Karl Lashley (1929). Recently,

progress has been made in the field of neuroscience, which comprises both the structural aspects of the brain and its peripheral components, as well as the functional aspects.

With the beginning of the twenty-first century, cognitive psychology seems poised to make another paradigm shift. While the traditional topics of perception, memory, language, problem solving, and thinking and the method of experimental analysis are still central to the cognitive theme. As is well known, the use of neuro cognitive imagery promises to become one of the major means of investigating cognitive functions in this century.

Neuro cognitive techniques, which have been developing very rapidly in the past several decades, allow us to see deeper and more clearly into the brain—and the brain is believed to be the engine of cognition. Virtually every area of cognition has been investigated with neuro cognitive techniques. These, techniques, MRI, PET, EEG, and the like, show not only the structures of cognition but also the processes involved. And, in many instance, the results have been remarkable. While this trend is likely to continue and grow, it is important to recognise the central themes in cognition mentioned above.

1.8 LET US SUM UP

Cognitive psychology is the study of how people perceive, learn, remember, and think about information. A cognitive psychologist might study how people perceive various shapes, why they remember some facts but forget others, or how they learn language.

Cognitive psychology is interested in what is generally called mental phenomena. In this sense, cognitive psychology IS the scientific study of the mind. Then we took up the various research methods that we use in cognitive psychology. Every research has a goal and it is achieved through appropriate methodology. It was noted that the goals of research in cognitive psychology was to find the how and why of thinking. It was pointed out that there are distinctive research methods in cognitive psychology. Each method has distinctive advantages and disadvantages. It was also noted that Cognitive psychologists often broaden and deepen their understanding of cognition through research in cognitive science. Cognitive science is a cross-disciplinary field that uses ideas and methods from cognitive psychology, psychobiology, artificial intelligence, philosophy, linguistics, and anthropology.

Modern cognitive psychology freely, draws theories and techniques; from twelve principal areas of research, namely cognitive neuroscience, human and artificial intelligence, perception, thinking and concept formation, pattern recognition, developmental psychology, attention, language, representation of knowledge, imagery, memory and consciousness. Then we dealt with a brief history of cognitive psychology and highlighted the early thoughts on thinking, renaissance and beyond and the status of cognitive psychology as of today. We then discussed some of the key issues in cognitive psychology highlighting nature vs. nurture, rationalism vs. empiricism, structure vs. processes etc.

1.9 UNIT END QUESTIONS

- 1) Describe the major historical schools of psychological thought leading up to the development of cognitive psychology.
- 2) Analyse how various research methods in cognitive psychology reflect empirist and rationalist approaches to gaining knowledge.
- 3) Design a rough sketch of a cognitive-psychological investigation involving one of the research methods described in this chapter. Highlight both the advantages and disadvantages of using this particular method for your investigation.
- 4) Describe Cognitive Psychology as it is today. How might you speculate that the field will change in the next 50 years?
- 5) How might an insight gained from basic research lead to practical use in an everyday setting?
- 6) Describe some real life situations related to different domains of cognitive psychology.
- 7) How might an insight gained from applied research lead to deepened understanding of fundamental features of cognition?
- 8) What was the importance of the computer to the development of cognitive psychology?
- 9) Next time you visit a supermarket or mall, pause for a few moments and observe the various examples of cognitive psychology which surround you. Pay particular attention to: 1) the use of forms and colours to gain attention, 2) your own reaction to environmental cues, 3) the use of memory in understanding language, context, and the interpretation of the sights and sounds of your environment. Note down your impressions of these matters and read them over in about a week. What principles discussed in this chapter apply?

1.10 SUGGESTED READINGS AND REFERENCES

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UNIT 2 INFORMATION PROCESSING IN LEARNING AND MEMORY

“The mechanisms of learning and memory are at the essence of how the brain works.”

— Brown

Structure

- 2.0 Introduction
- 2.1 Objectives
- 2.2 Learning and Memory
- 2.3 Cognitive Information Processing
 - 2.3.1 Principles of the Information Processing
- 2.4 Information Processing in Learning and Memory
 - 2.4.1 Cognitive Information Processing Model of Learning
 - 2.4.2 Development of Memory and Information Processing
- 2.5 Theories of Information Processing
 - 2.5.1 Designing Instruction that Incorporate Best Practices for Information Processing
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2.0 INTRODUCTION

One of the most fascinating and mysterious properties of the brain is its capacity to learn, or its ability to change in response to experience and to retain that knowledge throughout an organism’s lifetime. The ability to learn and to establish new memories is fundamental to our very existence; we rely on memory to engage in effective actions, to understand the words we read, to recognise the objects we see, to decode the auditory signals representing speech, and even to provide us with a personal identity and sense of self. Memory plays such an important and ubiquitous role that it is often taken for granted—the only time most people pay attention to their memory is when it fails, as too often happens through brain injury or disease.

2.1 OBJECTIVES

After reading this unit, you will be able to:

- Define the concept of learning and memory;
- Explain types of memory;
- Explain cognitive information processing; and
- Explain the theories of information processing.

2.2 LEARNING AND MEMORY

Learning is acquiring new knowledge, behaviours, skills, values, preferences or understanding, and may involve synthesising and processing different types of information. Benjamin Bloom (1965) has suggested three domains of learning

- 1) *Cognitive* – to recall, calculate, discuss, analyse, problem solve, etc.; *psychomotor* – to dance, swim, ski, dive, drive a car, ride a bike, etc.; and *affective* – to like something or someone, love, appreciate, fear, hate, worship, etc. These domains are not mutually exclusive. For example, in learning to play chess, the person will have to learn the rules of the game (cognitive domain); but he also has to learn how to set up the chess pieces on the chessboard and also how to properly hold and move a chess piece (psychomotor). Furthermore, later in the game the person may even learn to love the game itself, value its applications in life, and appreciate its history (affective domain).
- 2) *Memory* is usually divided into three storage systems: sensory, short-term, and long-term.

- i) *Sensory Memory* - Sensory memory is affiliated with the transduction of energy (change from one form of energy to another). The environment makes available a variety of sources of information (light, sound, smell, heat, cold, etc.), but the brain only understands electrical stimulation. The body has special sensory receptor cells that transduce this external energy to something the brain can understand. In the process of transduction, a memory is created. This memory is very short (less than 1/2 second for vision; about 3 seconds for hearing).

The sensory memory retains an exact copy of what is seen or heard (visual and auditory). It is absolutely critical that the learner attend to the information at this initial stage in order to transfer it to the next one. There are two major concepts for getting information into STM: *first*, individuals are more likely to pay attention to a stimulus if it has an interesting feature. *Second*, individuals are more likely to pay attention if the stimulus activates a known pattern.

- ii) *Short-Term Memory (STM)* - After entering sensory memory, a limited amount of information is transferred into short-term memory. Selective attention determines what information moves from *sensory memory* to *short-term memory*. STM is most often stored as sounds, especially in recalling words, but may be stored as images. It works basically the same as a computer's RAM (Random Access Memory) in that it provides a working space for short computations and then transfers it to other parts of the memory system or discards it. STM is vulnerable to interruption or interference. STM is characterised by:

A limited capacity of up to seven pieces of independent information (Miller, 1956).

The brief duration of these items last from 3 to 20 seconds.

Decay appears to be the primary mechanism of memory loss.

Miller's Magic Number - George Miller's classic 1956 study found that the amount of information which can be remembered on one exposure is between five and nine items, depending on the information. Applying a range of +2 or -2, the number 7 became known as *Miller's Magic Number*, the number of items which can be held in Short-Term Memory at any one time. Miller himself stated that his magic number was for items with one aspect. His work is based on subjects listening to a number of auditory tones that varied only in pitch. Each tone was presented separately, and the subject was asked to identify each tone relative to the others s/he had already heard, by assigning it a number. After about five or six tones, subjects began to get confused, and their capacity for making further tone judgments broke down. He found this to be true of a number of other tasks. But if more aspects are included, then we can remember more, depending upon our familiarity and the complexity of the subject (in Miller's research, there was only one aspect — the tone). For example, we can remember way more human faces as there are a number of aspects, such as hair color, hair style, shape of face, facial hair, etc. We remember phone numbers by their aspects of 2 or more groupings, i.e. chunking. We don't really remember "seven" numbers. We remember the first group of three and then the other grouping of four numbers. If it is long distance, then we add an area code. So we actually remember 10 numbers by breaking it into groups of three.

Within STM, there are three basic operations:

Iconic memory - The ability to hold visual images.

Acoustic memory - The ability to hold sounds. Acoustic memory can be held longer than iconic memory.

Working memory - Short-term memory is also called working memory and relates to what we are thinking about at any given moment in time. In Freudian terms, this is conscious memory. It is created by our paying attention to an external stimulus, an internal thought, or both. An active process to keep it until it is put to use (think of a phone number you'll repeat to yourself until you can dial it on the phone). Note that the goal is not really to move the information from STM to LTM, but merely put the information to immediate use.

- iii) *Long-Term Memory (LTM)* - This is relatively permanent storage. Information is stored on the basis of meaning and importance. The process of transferring information from STM to LTM involves the encoding or consolidation of information. This is not a function of time, that is, the longer a memory stayed in STM, the more likely it was to be placed into LTM; but on organising complex information in STM before it can be encoded into LTM. In this process of organisation, the meaningfulness or emotional content of an item may play a greater role in its retention into LTM. We must find ways to make learning relevant and meaningful enough for the learner to make the important transfer of information to long-term memory.

Also, on a more concrete level, the use of chunking has been proven to be a significant aid for enhancing the STM transfer to LTM. Remember, STM's

capacity is limited to about seven items, regardless of the complexity of those items. Chunking allows the brain to automatically group certain items together, hence the ability to remember and learn better.

The knowledge we store in LTM affects our perceptions of the world, and influences what information in the environment we attend to. LTM provides the framework to which we attach new knowledge. It contrasts with short-term and perceptual memory in that information can be stored for extended periods of time and the limits of its capacity are not known.

Schemas are mental models of the world. Information in LTM is stored in interrelated networks of these schemas. These, in turn, form intricate knowledge structures. Related schemas are linked together, and information that activates one schema also activates others that are closely linked. This is how we recall relevant knowledge when similar information is presented. These schemas guide us by diverting our attention to relevant information and allow us to disregard what is not important.

Since LTM storage is organised into schemas, instructional designers should activating existing schemas before presenting new information can be helpful in processing of the new information. This can be done in a variety of ways, including graphic organisers, curiosity-arousing questions, movies, etc.

LTM also has a strong influence on perception through *top-down processing* - our prior knowledge affects how we perceive sensory information. Our expectations regarding a particular sensory experience influence how we interpret it. This is how we develop bias. Also, most optical illusions take advantage of this fact. An important factor for retention of learned information in LTM is rehearsal that provides transfer of learning.

2.3 COGNITIVE INFORMATION PROCESSING

Information processing is the change (processing) of information in any manner detectable by an observer. Within the field of cognitive psychology, information processing is an approach to the goal of understanding human thinking. It began in the 1940s and 1950s. Educators are very interested in the study of how humans learn. This is because how one learns, acquires new information, and retains previous information guides selection of long-term learning objectives and methods of effective instruction. To this end, cognition as a psychological area of study goes far beyond simply the taking in and retrieving information. It is a broad field dedicated to the study of the mind holistically. Neisser (1967), one of the most influential researchers in cognition, defined it as the study of how people encode, structure, store, retrieve, use or otherwise learn knowledge. Cognitive psychologists hypothesise an intervening variable or set of variables between environment and behaviour—which contrasts it with behavioural theories.

2.3.1 Principles of the Information Processing

Even though there are widely varying views within cognitive psychology, there is general agreement among most cognitive psychologists on some basic principles of the information processing system (Huitt, 2000).

The *first* is the assumption of a limited capacity of the mental system. This means that the amount of information that can be processed by the system is constrained in some very important ways. Bottlenecks, or restrictions in the flow and processing of information, occur at very specific points (e.g., Broadbent, 1975; Case, 1978).

A *second* principle is that a control mechanism is required to oversee the encoding, transformation, processing, storage, retrieval and utilisation of information (e.g., Atkinson & Shiffrin, 1971). That is, not all of the processing capacity of the system is available; an executive function that oversees this process will use up some of this capability. When one is learning a new task or is confronted with a new environment, the executive function requires more processing power than when one is doing a routine task or is in a familiar environment.

A *third* principle is that there is a two-way flow of information as we try to make sense of the world around us. We constantly use information that we gather through the senses (often referred to as *bottom-up processing*) and information we have stored in memory (often called *top-down processing*) in a dynamic process as we construct meaning about our environment and our relations to it. This is somewhat analogous to the difference between inductive reasoning (going from specific instances to a general conclusion) and deductive reasoning (going from a general principle to specific examples.) A similar distinction can be made between using information we derive from the senses and that generated by our imaginations.

A *fourth* principle generally accepted by cognitive psychologists is that the human organism has been genetically prepared to process and organise information in specific ways. For example, a human infant is more likely to look at a human face than any other stimulus. Other research has discovered additional biological predispositions to process information. For example, language development is similar in all human infants regardless of language spoken by adults or the area in which they live (e.g., rural versus urban, Asia versus Europe.) All human infants with normal hearing babble and coo, generate first words, begin the use of telegraphic speech (example, ball gone), and overgeneralise (e.g., using “goed to the store” when they learn the verbs) at approximately the same ages (Discussed in detail in Block 3).

2.4 INFORMATION PROCESSING IN LEARNING AND MEMORY

One of the primary areas of cognition studied by researches is memory. There are many hypotheses and suggestions as to how this integration occurs, and many new theories have built upon established beliefs in this area. Currently, there is widespread consensus on several aspects of information processing; however, there are many dissensions in reference to specifics on how the brain actually codes or manipulates information as it is stored in memory.

Schacter and Tulving (as cited in Driscoll, 2001) state that “a memory system is defined in terms of its brain mechanisms, the kind of information it processes, and the principles of its operation”. This suggests that memory is the combined total of all mental experiences. In this light, memory is a built store that must be accessed in some way in order for effective recall or retrieval to occur. It is

premised on the belief that memory is a multi-faceted, if not multi-staged, system of connections and representations that encompass a lifetime's accumulation of perceptions.

Eliasmith (2001) defines memory as the “general ability, or faculty that enables us to interpret the perceptual world to help organise responses to changes that take place in the world”. It is implied by this definition that there must be a tangible structure in which to incorporate new stimuli into memory. The form of this structure has been the source of much debate, and there seems to be no absolute agreement on what shape a memory structure actually takes, but there are many theories on what constitutes both the memory structure and the knowledge unit.

Winn and Snyder (2001) attribute the idea that memory is organised into structures to the work of Sir Frederick Charles Bartlett. Bartlett's work established two consistent patterns regarding recall. First, memory is inaccurate. His second finding, though, brought about somewhat of a revolution in traditional thinking about memory. Bartlett suggested that the inaccuracy of memory is systematic. A systematic difference makes allowable the scientific study of inaccuracy, and this suggestion led to an entirely new mode of thought on memory. What accounted for systematic inaccuracies in memory were the intervening influences of previous information and the experiences of the person. This demonstrates that knowledge units are not simply stored and then left alone, but that they are retained, manipulated, and changed as new knowledge is acquired.

2.4.1 Cognitive Information Processing Model (CIP) of Learning

Information theorists approach learning primarily through a study of memory. The following Cognitive Information Processing model (CIP) of learning presents a well-established paradigm of cognitive-behavioural psychology. The model articulates the limited capacity of “working memory.” Working memory is tasked with the burden of processing incoming information, transferring information to long-term memory and retrieval of information from long-term memory. The concept of “cognitive load” — the amount of work imposed on working memory by a learning task — is based on observations of the functions of working memory.

Information processing in memory can be viewed from a computer model perspective. Like the computer, the human mind takes in information, performs operations on it to change its form and content, stores the information, retrieves it when needed, and generates responses to it. Processing involves *encoding* (gathering and representing information); *storage* (holding information); and *retrieval* (getting the information when needed). The entire system is guided by a *control process* that determines how and when information will flow through the system. Some theorists suggest that the operation of the brain resembles a large number of computers all operating at the same time (in parallel).

2.4.2 Development of Memory and Information Processing

As previously stated, cognition is the encoding, structuring, storing, retrieving, using, or otherwise learning knowledge (Neisser, 1967). There are important developmental aspects for each of these activities. According to Flavell et al. (2002), from an information processing perspective some of the most important are:

- Brain changes brought about by biological maturation or experience;
- Increased processing capacity, speed, and efficiency as a result of both maturation and knowledge development;
- Modifications of connections in a neural network;
- New emergent concepts arising from repeated self-organisation as a result of adapting to the demands of a changing environment; and
- Increased capacity for problem-solving and metacognition.

Encoding - Encoding occurs during the initial processing of a stimulus or event. Maturation and experience influence this process. In terms of maturation, Dempster (1981) suggests that the adult capacity for short-term memory of 5 + 2 digits might be as much as 2 digits lower for children aged 5 and 1 digit lower for children aged 9. As for experience, in a series of well-known studies of expertise, novices remember new information less well than experts (e.g., Chi, 1978; Schneider, Korkel, & Winert, 1989). One of the most important differences between novices and experts is the structure and organisation of domain-specific knowledge.

Structuring and Organising - Structuring and organising information occur as the learner processes and stores information. The learner's ability changes over time as a result of both maturation and experience. When presented with information they are asked to remember, younger children do not rehearse information in order to remember it. As they get into school, they begin to develop or are taught various strategies. At first these strategies are only used when prompted by someone else, but as the child becomes more competent in their use and uses them more frequently, the child will increasingly use the strategies spontaneously (Flavell et al., 2002).

One of the most important information processing capacities a child develops is the ability to organise information; this is, in turn, influenced by the child's ability to categorise. As is the case with other information-processing capacities, this ability changes with both maturation and experience.

One of the basic types of categorisation is the grouping of specific events, ideas, people, things, etc. into concepts. Rosch and his colleagues (e.g., Mervis & Rosch, 1981; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) demonstrated two fundamental features to the development of concepts: the ease of identifying similarities of members of the concept and distinguishing differences between members that are not. For example, the development of the concept of animal would be more difficult than developing the concept of dog or cat because it would be easier to identify similarities among dogs or cats and differences between cats and dogs than it would be to identify similarities among all animals or to differentiate all animals from all plants.

This has important implications as we design learning activities for children and youth that can help them develop their organisational and storage capacities.

Storage and Retrieval - How much information can be stored and retrieved relative to a stimulus or event also changes over time. For example, prior to about age 7 months an infant will not seek an object that has been shown and then removed from view. The infant has encoded the object (such as a rattle) and

will reach for it, but seems to lose interest as soon as it is no longer in view. At about 7 months attains what is called “object permanence” and will begin to seek the object if it is removed from view.

A series of studies by Bauer, Mandler and associates (as cited in Flavell et al., 2002) demonstrates a child’s increasing ability to perform simple multiple-act sequences. By age 13 months infants can reproduce three-act sequences; by age 24 months this has increased to five-act sequences; and by age 30 months to eight separate actions. As children gain language skills, their ability to store and recall more complex events increases. This is shown first in autobiographical accounts of daily activities and then to events they may have witnessed or heard about.

Flavell et al. (2002) made four observations about strategy development:

Strategy development is not linear. When developing any particular strategy, development will often stall or even regress before it becomes systematically and correctly used.

A strategy will continue to develop after it is first demonstrated in its mature form. This continued development may take months or even years.

Children show considerable variability in their use of strategies. Children often go back and forth in their use of strategies, changing strategies even after they have been found to work well.

Children differ in their abilities to integrate different strategies into a coherent pattern for successful learning. Children must be given ample opportunity to create successful learning programs that work for them.

2.5 THEORIES OF INFORMATION PROCESSING

There are important theories which explain information processing. Some of the major theories are presented in the following section.

2.5.1 Designing Instruction that Incorporates Best Practices for Information Processing

The understanding of how the mind processes and stores information is invaluable to educators as they plan for instruction. If there is little to no understanding of the information processing skills of the students with whom one is working, it would be almost impossible to design instruction that contributes to high levels of learning and achievement. However, attempting to understand the myriad theories of information processing and cognitive development can be overwhelming and contradictory. There are means of structuring instruction, though that can incorporate the best of all of these ideas, and in order to help students reach higher-level thinking and learning skills, educators must draw from all of these theories.

If learning is to occur, educators must ensure that new information is processed in such a way that it can be retained in long-term memory. In order to achieve this, elaboration and connection must occur between previously learned memory and new information. It has been established that the more deeply information is processed and the more connections that can be made between new information and existing memory structures, the more information will be retained in long-

term memory. Therefore, in order to make new material meaningful, instruction must be presented in such a way that students can easily access and connect previous learning and experiences with the new material. One of the most often cited references to levels of elaboration for instructional purposes is the Taxonomy of the Cognitive Domain developed by Bloom and his colleagues (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956) and recently revised by Anderson and Krathwohl (2000).

2.5.2 Bloom's Taxonomy of Cognitive Domain

Bloom et al. (1965) proposed that information processing can be classified in six levels, each more complex than the previous. The first level is labeled *knowing* and simply requires a learner to repeat back what was heard or seen. This involves very little elaboration. The second level is labeled *comprehension* and requires some rudimentary levels of understanding that might involve having the student summarize or paraphrase some information. Again, this requires only modest levels of elaboration. The next two levels, *application* and *analysis*, involve more elaboration and show a significant impact on long-term learning when they are used during the learning process. Application involves using the concepts or principles to solve a problem, while analysis involves understanding the relationship among the parts and how they are organised into a whole. The last two levels, *synthesis* and *evaluation*, are the most complex and require the highest levels of elaboration. Synthesis involves putting the parts or components together in an original manner, while evaluation is the process of making judgments based on comparison to a standard.

Research has confirmed that the first four levels are indeed a hierarchy, while there seems to be a problem with the ordering of the two highest levels (Hummel & Huitt, 1994). Anderson and Krathwohl (2000) propose that the ordering is reversed, with evaluation being less difficult than synthesis, while Huitt (2000) proposes that they are both at the same level of difficulty though they incorporate different types of processing. There seems to be consensus that both synthesis and evaluation are based on analysis or the ability to compare and contrast parts of a whole and understand the relationship among parts.

2.5.3 Sternberg's Information Processing Approach

Another theorist firmly grounded in the information processing approach is Sternberg (1988). Sternberg's theory suggests that development is skills-based and continuous rather than staged and discontinuous as stage theorists believe, and his focus is on intelligence. This focus on intelligence separates his ideas from stage theorists because it rejects the idea of incremental stages, but rather suggests that development occurs in the same way throughout life differentiated only by the expertise of the learner to process new information. First, and very importantly, Sternberg's model does not differentiate between child and adult learning. Also, he deals solely with information processing aspects of development and does not incorporate any facets of biological development into his theory. Cognitive development is viewed as a novice to expert progression; as one becomes better at interaction and learning, one is able to learn more and at higher levels. Development changes as a result of feedback, self-monitoring, and automatisisation. In this theory, intelligence is comprised of three kinds of information processing components: metacomponents, performance components, and knowledge-acquisition components.

In Sternberg's (1988) model, each of these three components works together to facilitate learning and cognitive development. Metacomponents are executive in nature. They guide the planning and decision making in reference to problem solving situations; they serve to identify the problem and connect it with experiences from the past. There is, however, no action directly related to metacomponents, they simply direct what actions will follow. Performance components are the actions taken in the completion of a problem-solving task. Performance components go beyond metacomponents in that they perform the function also of weighing the merit and or consequences of actions in comparison to other options rather than simply identifying options. Sternberg's third proposed type of intelligence is the knowledge-acquisition component. This type is characterised by the ability to learn new information in order to solve a potential problem. This type is much more abstract and may or may not be directly related to a current problem-solving task (Driscoll, 2001). This three-leveled view of intelligence comprises the componential aspect of Sternberg's theory, but this is only one of three parts to his larger triarchic theory of intelligence (Kearsley, 2001).

Sternberg's (1988) theory adds the components of feedback to theories of cognitive development; this suggests that an individual's social interaction has some impact on cognitive development. In fact, one of the three parts of his theory is based on the context in which learning takes place; this subpart of the theory "specifies that intelligent behaviour is defined by the sociocultural context in which it takes place and involves adaptation to the environment, selection of better environments, and shaping of the present environment" (Kearsley, 2001). The addition of social context as a factor in cognitive development links Sternberg to the interactional theories of development of Bruner (1977, 1986) and Vygotsky (1978). These theories, and others of this type, are premised on the assumption that learning does not occur in a vacuum. Therefore, one must discuss the social and cultural contexts of learning. Driscoll (2001) says, "Of central importance is viewing education as more than curriculum and instructional strategies. Rather, one must consider the broader context in how culture shapes the mind and provides the toolkit by which individuals construct worlds and their conceptions of themselves and their powers".

These theories all work under the assumption that new information can most effectively be learned if the material can be matched to memory structures already in place (Winn and Snyder, 2001). Most theories hold that the mind contains some type of framework into which new information is placed. This structure is multi-leveled and has varying degrees of specificity. New information can be matched with, compared to, contrasted to, joined with, or modified to fit with existing structures. This in-place structural system allows for differing levels of complexity of information processing. The formation of and continual building of these structures, then, is critical in order for learners to process information in various ways and at higher levels.

2.6 LET US SUM UP

One of the most fascinating and mysterious properties of the brain is its capacity to learn, or its ability to change in response to experience and to retain that knowledge throughout an organism's lifetime. The ability to learn and to establish new memories is fundamental to our very existence; we rely on memory to engage

in effective actions, to understand the words we read, to recognise the objects we see, to decode the auditory signals representing speech, and even to provide us with a personal identity and sense of self.

Learning is acquiring new knowledge, behaviours, skills, values, preferences or understanding, and may involve synthesising and processing different types of information.

Memory is usually divided into three storage systems: sensory, short-term, and long-term.

We then discussed Miller's Magic number. We pointed out how within STM, there are 3 basic operations, viz., iconic memory, acoustic memory and working memory. Long Term Memory has been then presented which includes schemas etc. Then the principles of information processing was taken up and highlighted the limited capacity of the mental system and secondly the control mechanism is required to oversee the encoding, transformation, processing storage etc.

Then we dealt with information processing in learning and memory. It was pointed out that from an information processing perspective some of the most important aspects include

- Brain changes brought about by biological maturation or experience;
- Increased processing capacity, speed, and efficiency as a result of both maturation and knowledge development;
- Modifications of connections in a neural network;
- New emergent concepts arising from repeated self-organisation as a result of adapting to the demands of a changing environment; and
- Increased capacity for problem-solving and metacognition.

Then we discussed about encoding which involves structuring, organising, storage, retrieval etc. This was followed by theories of information processing which highlighted Bloom's Taxonomy and Sternberg's information processing theory. It was pointed out that that new information can most effectively be learned if the material can be matched to memory structures already in place. Most theories hold that the mind contains some type of framework into which new information is placed. This structure is multi-leveled and has varying degrees of specificity. New information can be matched with, compared to, contrasted to, joined with, or modified to fit with existing structures.

2.7 UNIT END QUESTIONS

- 1) Describe two characteristics each of sensory memory, short term memory, and long term memory.
- 2) Discuss the information processing approaches of learning and memory.
- 3) How would you design a study program to process the information so that it can be retained in long term memory?
- 4) Describe the development of memory with reference to information processing.

- 4) How would your life be different if you could greatly enhance your memory skills?
- 5) What are the basic principles of information processing?
- 6) What are the three things you have learned about memory that can help you learn new information so that you can effectively recall the information over the long-term?

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UNIT 3 NEUROPSYCHOLOGICAL BASIS OF LEARNING AND MEMORY

“It’s a sense of flooding the brain too quickly. The brain has this disruption, and the short-term memory isn’t converting into long-term memory.”

– John Hamilton

Structure

- 3.0 Introduction
- 3.1 Objectives
- 3.2 Memory and Brain
 - 3.2.1 Human Memory, Brain Damage and Amnesia
 - 3.2.2 Brain Surgery and Memory Loss
 - 3.2.3 Amnesia and the Medial Temporal Lobe
- 3.3 Memory Consolidation and Hippocampus
- 3.4 Anterior and Lateral Temporal Lobes and Memory
- 3.5 Animal Models of Memory
- 3.6 Imaging the Human Brain and Memory
 - 3.6.1 Episodic Encoding and Retrieval
 - 3.6.2 Semantic Encoding and Retrieval
 - 3.6.3 Procedural Memory Encoding and Retrieval
 - 3.6.4 Perceptual Priming and Implicit and Explicit Memory
- 3.7 Cellular Bases of Learning and Memory
- 3.8 Let Us Sum Up
- 3.9 Unit End Questions
- 3.10 Suggested Readings and References

3.0 INTRODUCTION

What is the relationship between learning and memory? Learning is the process of acquiring new information, whereas memory refers to the persistence of learning in a state that can be revealed at a later time (Squire, 1987). Learning, then, has an outcome, and we refer to that as *memory*. To put it another way, learning happens when a memory is created or is strengthened by repetition. This need not involve the conscious attempt to learn. Learning can occur and performance can improve simply from more exposure to information or to a task. For example, we remember the details of a person’s face better by seeing it more, without having to try to consciously memorize facial features.

Learning and memory can be subdivided into major hypothetical stages: encoding, storage, and retrieval. Encoding refers to the processing of incoming information to be stored. The encoding stage has two separate steps: acquisition and consolidation. Acquisition registers inputs in sensory buffers and sensory analysis stages, while consolidation creates a stronger representation over time. Storage, the result of acquisition and consolidation, creates and maintains a permanent record. Finally, retrieval utilises stored information to create a conscious representation or to execute a learned behaviour like a motor act.

We search for the neural correlates of learning and memory in many ways: a) through case studies which reveal what is and is not lost in amnesia; b) by developing animal models of memory in simple (invertebrates) and complex systems (nonhuman primates); c) and with brain imaging to investigate normal encoding, retrieval, and recall in healthy humans. In this chapter we will explore all these methods in brief in order to understand the neural basis of learning and memory.

3.1 OBJECTIVES

After reading this unit, you will be able to:

- Describe the process of memory in the brain;
- Define neurological issues related to memory;
- Define neuropsychological basis of learning and memory;
- Explain the neural processes of learning and memory.

3.2 MEMORY AND BRAIN

The field of the cognitive and experimental psychology of memory is rich with theory and data and has produced a consistent set of concepts about the organisation of human memory. The neuro scientific studies of memory are important, both to understand how they have contributed to general theories of memory, and to investigate how specific neural circuits and systems enable the learning and retention of specific forms of knowledge.

3.2.1 Human Memory, Brain Damage and Amnesia

Deficits in memory as a function of brain damage, disease, or psychological trauma are known as amnesia. Amnesia can involve either the inability to learn new things or a loss of previous knowledge, or both. It can differentially affect short-term/ working memory and long-term memory abilities. Thus, by examining amnesia in conjunction with cognitive theories derived from experiments on normal subjects, we can understand the organisation of memory at a functional and a neural level. Much compelling information about the organisation of human memory during amnesia was first derived from medical treatments that left patients amnesic. The history is fascinating, and so let's begin by turning back the clock more than fifty years.

3.2.2 Brain Surgery and Memory Loss

In the late 1940s and early 1950s, surgeons attempted to treat neurological and psychiatric disease using a variety of neurosurgical procedures, including prefrontal lobotomy (removing or disconnecting the prefrontal lobe), corpus callosotomy (surgically sectioning the corpus callosum), amygdalotomies (removing the amygdala), and temporal lobe resection (removal of the temporal lobe) (Figure 1.3.1). These surgical procedures opened a new window on human brain function as they revealed, usually quite by accident, fundamentally important principles of the organisation of human cognition. One surgical procedure relevant to memory was removal of the medial portion of the temporal lobe, including the hippocampal formation.

In 1953 at a medical conference, the neurosurgeon William Beecher Scoville from the Montreal Neurological Institute reported on bilateral removal of the medial temporal lobe in one epileptic patient and several schizophrenic patients. Shortly thereafter he wrote:

Bilateral resection of the uncus, and amygdalum alone, or in conjunction with the entire pyriform amygdaloid hippocampal complex, has resulted in no marked physiologic or behavioural changes with the one exception of a very grave, recent memory loss, so severe as to prevent the patient from remembering the locations of the rooms in which he lives, the names of his close associates, or even the way to the toilet.... (Scoville, 1954).

Scoville and psychologist Brenda Milner did the neuropsychological examination of ten patients. Milner found that memory impairments in the patients having medial temporal lobe resections as part of their treatment were in relation to how much of the medial temporal lobe was removed. The farther posterior along the medial temporal lobe the resection was, the worse the amnesia. Strikingly, however, only *bilateral* resection of the hippocampus resulted in severe amnesia. In comparison, in one patient whose entire right medial temporal lobe (hippocampus and hippocampal gyrus) was removed, no residual memory deficit was found (Figure 1.3.1). But the interesting patient was the young man who had had bilateral medial temporal resection.

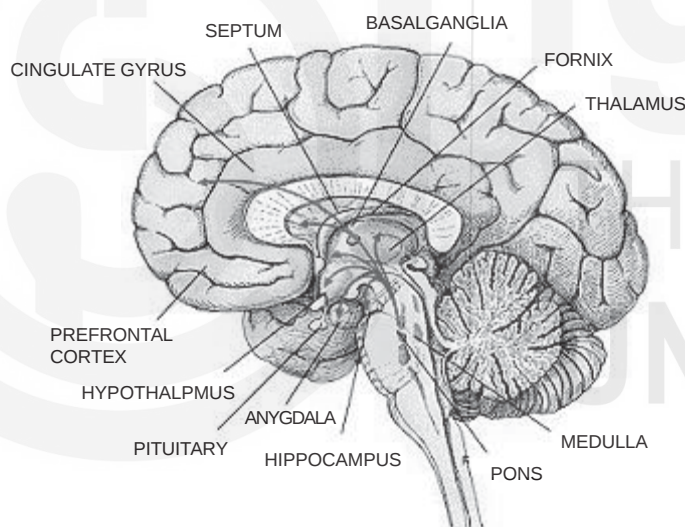


Fig. 1.3.1: Medial view of Human Brain (Source: Net)

The case history of patient H.M. – H.M. was a young man who suffered from a difficult-to-treat form of epilepsy that progressed in severity during his teen years. Over the years his physicians had treated him with the available drugs to minimize his seizures, but these drugs were largely ineffective for him. As his seizures worsened in his twenties, he decided to try a then-radical new therapy that involved surgery. At that time neurologists knew that many seizures originated in the medial portions of the temporal lobe and from there spread to other areas of the brain, leading to violent seizures and often loss of consciousness. It was also becoming increasingly clear that surgically removing the brain region in which the seizure activity originated, the so-called seizure focus, could help patients with epilepsy. The decision in H.M.'s case was to remove his medial temporal lobe bilaterally, in a procedure called temporal lobectomy

Following recovery from this major neurosurgical procedure, H.M.'s epilepsy did improve. The surgery was a success, both with regard to his surviving the risks associated with any surgery of the brain and with regard to the epilepsy. However, physicians, family, and friends began to realise that H.M. was experiencing new difficulties. For example, a year and a half after the surgery, which was performed in September 1953, H.M. displayed clear problems with his memory. Although it was April 1955 and H.M. was 29 years old, he reported his age to be 27. H.M. would say he did not remember ever meeting certain individuals, even when he actually spoke to them a few minutes earlier and they merely left the room, returning after a short delay! H.M. was profoundly amnesic—that is, he suffered from disorders of memory. However, H.M. did not have the kind of amnesia one sees depicted in television shows or movies, where the character has a total loss of all prior memories. Indeed, H.M. knew who he was and could remember things about his life—that is, up until a period prior to his surgery. However, it became increasingly clear that H.M. could not form new long-term memories.

Formal neuropsychological tests were performed on H.M. to establish the nature of his cognitive deficits. These tests showed that his intelligence was well above normal after the surgery. He also had no perceptual or language problems and seemed generally fine, with no changes in his personality or motivation. However, when memory tests were administered, H.M. scored well below normal. The bilateral removal of H.M.'s medial temporal lobe produced a highly selective deficit in his memory ability, leaving other cognitive functions intact. H.M. had normal short-term memory (sensory registers and working memory), but he developed a severe and permanent inability to acquire and store new information (Figure 1.3.2). The transfer of information from short-term storage to long-term memory was disrupted.

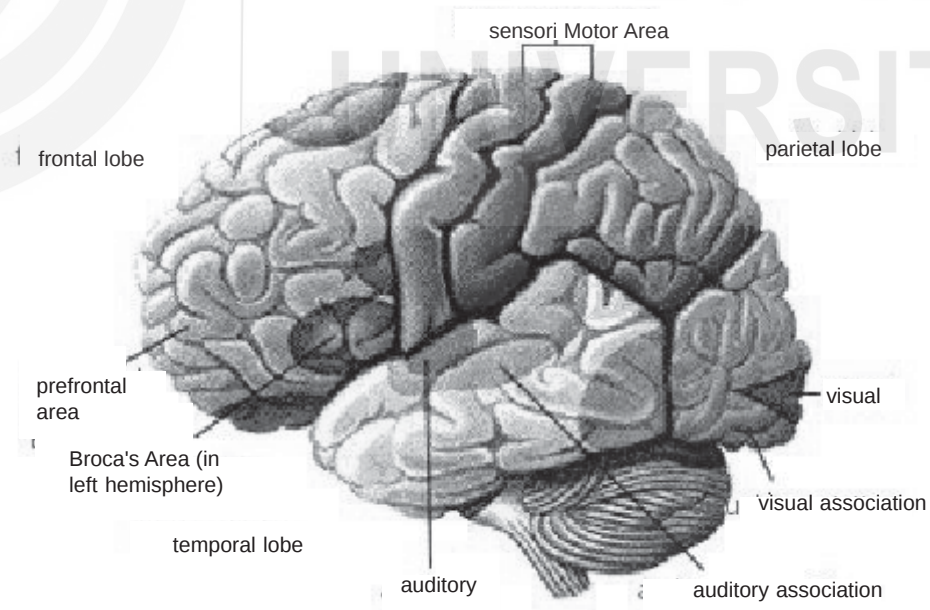


Fig. 1.3.2: Major Areas of the Brain (Source: InterNet)

3.2.3 Amnesia and the Medial Temporal Lobe

Which region or regions of the medial temporal lobe were critical for supporting the long-term memory ability lost in H.M.? The medial temporal area includes

the amygdala, the hippocampus, the entorhinal cortex, and the surrounding parahippocampal and perirhinal cortical areas (Figure 1.3.1).

For the past 40 years, scientists studying H.M. used surgical reports of his lesions to guide theories of memory and “amnesia and their neural bases. Reports by Scoville, who performed the surgery, indicated that all of H.M.’s hippocampus in each hemisphere had been removed. H.M.’s brain and surgical lesions were re-evaluated with improved accuracy with high-resolution neuroimaging methods such as magnetic resonance imaging (MRI), and it was found that in addition to the hippocampus, some of H.M.’s surrounding cortex was also removed.

Is damage to the hippocampus sufficient to block the formation of new long-term memories? Consider another patient, R.B., who lost his memory after an ischemic episode (reduction of blood to brain) during bypass surgery. R.B. developed dense anterograde amnesia similar to H.M.’s. He could not form new long-term memories. He also had retrograde amnesia that extended back to 1 to 2 years, slightly less severe than H.M.’s retrograde loss. After his death, R.B.’s brain was donated for study, permitting a detailed analysis of the extent of his neuroanatomical damage. In R.B.’s case, lesions were found to be restricted to his hippocampus; within each hippocampus, R.B. had sustained a specific lesion restricted to the CA1 pyramidal cells.

These findings in patient R.B. support the idea that the hippocampus is crucial in forming new long-term memories. R.B.’s case also supports the distinction between areas that store long-term memories and the role of the hippocampus in forming new memories. Even though retrograde amnesia is associated with medial temporal lobe damage, it is temporally limited and does not affect long term memories of events that happened more than a few years prior to the amnesia-inducing event.

3.3 MEMORY CONSOLIDATION AND HIPPOCAMPUS

Memories are solidified in long-term stores over days, weeks, months, and years. This process is referred to as consolidation, an old concept that refers to how long term memory develops over time after initial acquisition. From a cognitive neuroscience perspective, consolidation is conceived of as biological changes that underlie the long-term retention of learned information, and we can ask what brain structures and systems support this process.

Because damage to the medial temporal lobe does not wipe out most of the declarative memories formed over a lifetime, we know that the hippocampus is not the repository of stored knowledge. Rather, the medial temporal lobe appears to support the process of forming new memories; that is, the hippocampal region is critical for the consolidation of information in long term memory. The strongest evidence that the hippocampus is involved in consolidation comes from the fact that amnesics have retrograde amnesia for memories from one to a few years prior to the damage to the medial temporal lobe or diencephalon, a pattern that does not support a storage role but rather a role in consolidation.

What might consolidation entail at the neural level? One idea is that consolidation strengthens the associations between multiple stimulus inputs and activations of

previously stored information. The hippocampus is hypothesised to coordinate this strengthening, but the effects are believed to take place in the neocortex. The idea is that once consolidation is complete, the hippocampus is no longer required for storage or retrieval. Nonetheless, keep in mind that although the memories are stored in the neocortex, the hippocampus is crucial for consolidation.

Alcoholic Korsakoff's Syndrome and Diencephalic Amnesia - The medial temporal lobe is not the only area of interest in human memory. Amnesia emerges from brain damage in other regions too. For example, damage to midline structures of the diencephalon of the brain causes amnesia. The prime structures are the dorsomedial nucleus of the thalamus and the mammillary bodies (Figure 1.3.2). Damage to these midline subcortical regions can be caused by stroke, tumors, and metabolic problems like those brought on by chronic alcoholism as well as by trauma.

In the last half of the nineteenth century, the Russian psychiatrist Sergei Korsakoff reported an anterograde and retrograde amnesia associated with alcoholism. Long term alcohol abuse can lead to vitamin deficiencies that cause brain damage. Patients suffering from alcoholic Korsakoff's syndrome have degeneration in the diencephalon, especially the dorsomedial nucleus of the thalamus and the mammillary bodies. It remains unclear whether the dorsomedial thalamic nucleus, the mammillary bodies, or both are necessary for the patients' amnesia. Nonetheless, damage to the diencephalon can produce amnesia.

3.4 ANTERIOR AND LATERAL TEMPORAL LOBES AND MEMORY

If, as suggested earlier, the neocortex is crucial for the storage of memories, then it should be possible to demonstrate retrograde amnesia with cortical damage, even though most amnesias are anterograde. In line with this proposal, amnesia can be caused by damage to regions of the neocortex.

One region of special interest is the temporal neocortex outside the medial temporal lobe. Lesions that damage the lateral cortex of the anterior temporal lobe, near the anterior pole, lead to a dense amnesia that includes severe retrograde amnesia; in such cases the entorhinal cortex and perihippocampal cortex may be involved. The retrograde amnesia may be severe, extending back many decades before the amnesia-inducing event occurred or encompassing the patient's entire life. Various forms of damage can lead to this condition. Progressive neurological diseases like Alzheimer's, and herpes simplex encephalitis involving viral infection of the brain are two such conditions.

Some patients with dense retrograde amnesia might still form new long-term memories. This type of amnesia is called *isolated* retrograde amnesia. It is particularly related to damage of the anterior temporal lobe. This portion of the temporal lobe is not, therefore, essential for acquiring new information.

Are these lateral and anterior regions of the temporal lobe the sites of storage of long-term declarative memories? The answer is maybe, but another view is that these regions may be particularly important for the retrieval of information from long-term stores. Where then are memories stored? More recent evidence from

neuroimaging studies suggests that memories are stored as distributed representations throughout neocortex, involving the regions that originally encoded the perceptual information and regions representing information that was associated with this incoming information (as noted in the last section, the medial temporal lobe may coordinate the consolidation of this information over time).

3.5 ANIMAL MODELS OF MEMORY

Studies in monkeys with lesions to the hippocampus and surrounding cortex have been invaluable in learning about the contributions of the medial temporal lobe to primate memory systems. In general, the goal of such research is to develop animal models of human memory and amnesia. Through research, such models are providing key information on relations between specific memory and brain structures. Several animal species, ranging from invertebrates to monkeys, have been investigated *for* clues to human memory and its functional neuroanatomy and neurobiology; it is likely that monkeys will contribute the most directly applicable knowledge about human processes at the systems level given the similarity among primate brains. We must always keep in mind, however, that the gross organisation and functional capabilities of the brains of monkeys and humans differ significantly. Thus, animal models of cognitive processes like memory are perhaps most informative when linked with studies in humans.

One of the key questions in memory research was how much the hippocampus alone, as compared with surrounding structures in the medial temporal lobe, participated in the memory deficits of patients like H.M. In other words, what structures of the medial temporal lobe system are involved in episodic memory? For example, does the amygdala influence memory deficits in amnesics? Data from amnesics indicate that the amygdala is not part of the brain's episodic memory system, although it has a role in emotion and emotional memories.

To verify this, surgical lesions were created in the medial temporal lobe and amygdala of monkeys, to cause memory impairment. In classic work by Mortimer Mishkin (1978) at the National Institute of Mental Health (NIMH), the hippocampus or the amygdala, or both the hippocampus and the amygdala, of monkeys were removed surgically. He found that the amount of impairment, as measured on tests, varied according to what was lesioned.

In his early work, Mishkin found that in the monkey, memory was impaired only if the lesion included the hippocampus and amygdala. This led to the idea that the amygdala was a key structure in memory. The idea does not fit well with data from amnesics like R.B., who had anterograde amnesia caused by a lesion restricted to neurons of the hippocampus and no damage to the amygdala. Stuart Zola and colleagues (1993) at the University of California at San Diego investigated this dilemma. They performed more selective lesions of the brains of monkeys by distinguishing between the amygdala and hippocampus, as well as the surrounding cortex near each structure. They surgically created lesions of the amygdala, the entorhinal cortex, or the surrounding neocortex of the parahippocampal gyrus and the perirhinal cortex (Brodmann's areas 35 and 36) (Figure 1.3.3).

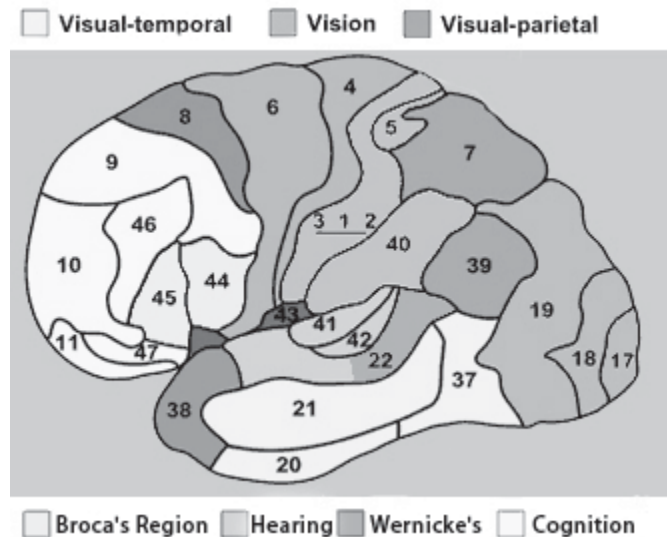


Fig. 1.3.3: Broca's areas of the Brain (Source: Net)

They found that lesions of the hippocampus and amygdala produced the most severe memory deficits only when the cortex surrounding these regions was also lesioned. When lesions of the hippocampus and amygdala were made but the surrounding cortex was spared, the presence or absence of the amygdala lesion did not affect the monkey's memory. The amygdala, then, could not be part of the system that supported the acquisition of long-term memory.

In subsequent investigations, Zola and his colleagues selectively created lesions of the surrounding cortex in the perirhinal, entorhinal, and parahippocampal regions. This worsened memory performance in delayed nonmatching to sample tests. Follow-up work showed that lesions of only the parahippocampal and perirhinal cortices also produced significant memory deficit.

How does this make sense in relation to R.B.'s profound anterograde amnesia with damage limited to the hippocampus and not involving the surrounding parahippocampal or perirhinal cortex? The parahippocampal and perirhinal areas receive information from the visual, auditor, and somatosensory association cortex and send these inputs to the hippocampus, and from there to other cortical regions. The hippocampus cannot function properly if these vital connections are damaged. But more than this, we now also know that these regions are involved in much processing themselves, and hence lesions restricted to the hippocampus do not produce as severe a form of amnesia as do lesions that include surrounding cortex.

In summary, the data from animals are highly consistent with evidence from amnesic patients such as R.B. and H.M. that implicates the hippocampal system in the medial temporal lobe and the associated cortex as critical for forming long-term memories. Lesions that damage the hippocampus directly, or damage the input-output relation of the hippocampus with the neocortex, produce severe memory impairments. The amygdala is not a crucial part of the system for episodic memory but is important for emotional memory. Moreover, the animal data match well with those from amnesics with regard to the preservation of short-term memory processes after the medial temporal lobe has been damaged; monkeys memory deficits in the delay mismatching to sample task became more pronounced as the interval between the sample and test increased. The medial temporal lobe, then, is not essential for short-term or working memory processes.

As we noted earlier, the medial temporal lobe is not the locus of long-term storage because retrograde amnesia is not total after damage to this area; rather, the medial temporal lobe is a key component in organising and consolidating long-term memory that is permanently stored in a distributed fashion in the neocortex.

3.6 IMAGING THE HUMAN BRAIN AND MEMORY

The work described so far has dealt with evidence from humans and animals with brain damage. These data are consistent with regard to the role of the medial temporal lobe in memory. Over the past decade, there has been an exponential increase in studies of normal subjects using functional brain imaging methods. The results are quite provocative and are confirming and extending the findings from lesion studies. In the following, we review recent studies of the brain organisation of episodic memory, semantic memory, procedural memory, and the perceptual representation system (PRS).

3.6.1 Episodic Encoding and Retrieval

Given the purported role of the hippocampus system in encoding memory in long-term stores, researchers have eagerly addressed this issue using positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). One such line of work involved face encoding and recognition. The question was whether the Hippocampus becomes active when encoding new information. James Haxby, Leslie Ungerleider, and their colleagues (1996) at the NIMH presented subjects with pictures of either faces or nonsense patterns, and, using PET, investigated memory performance. In different conditions subjects were required to remember (encode) the face, recognise the face, and perceptually analyse the face by comparing two faces. During these periods, PET scans recorded changes in regional cerebral blood flow triggered by local neuronal activity.

These investigators observed that the right hippocampus region was activated during encoding of the face but not during recognition, where retrieval processes should have been engaged. These data are consistent with those from amnesic patients who had medial temporal lobe damage that led to anterograde amnesia but preserved distant retrograde memories. Encoding also activated the left prefrontal cortex, whereas recognition activated the right prefrontal cortex. Thus, we have more support for the hippocampus's role in memory, as well as possible support for hemispheric asymmetries in memory functions.

Encoding and retrieval processes were lateralised in the left and right hemispheres, respectively, giving rise to a model with the acronym of HERA, which stands for "hemispheric encoding-retrieval asymmetry." This model represents the idea that encoding involves the left hemisphere more than the right, and retrieval involves the right hemisphere more than the left. Both processes predominantly involve the dorsolateral prefrontal cortex. In encoding and retrieving information from long-term memory, neocortical areas were the most activated.

Some more recent studies made use of event-related fMRI methods to track the processing of individual items as a function of the success of the encoding, as indexed by later memory performance. Anthony Wagner and his colleagues at MIT, Harvard University, and Massachusetts General Hospital (1998), and John

Gabrieli and his colleagues at Stanford (Brewer et al., 1998) conducted such studies. They presented subjects with items and scanned their brains using of MRI while they were encoding the information, and then later tested them for their memories of the items. Each research group found that event-related responses were larger in prefrontal and medial temporal regions (parahippocampal cortex) during encoding of words or pictures that were later remembered.

3.6.2 Semantic Encoding and Retrieval

The encoding and retrieval of semantic knowledge also have been studied using functional neuroimaging, and significant new findings have been uncovered. In particular, evidence for domain-specific organisation (i.e., knowledge of animate and inanimate objects is localised in different cortical regions) has proved to be a fascinating story. Unlike episodic retrieval that activates the right prefrontal cortex, semantic retrieval involves the left prefrontal cortex. The region includes Broca's area (Brodmann's area 44 extending into area 46) and the ventral lateral region (Brodmann's areas 44 and 45) (Figure 1.3.3). This lateralisation to the left hemisphere remains regardless of whether the memories being retrieved are of objects or words.

3.6.3 Procedural Memory Encoding and Retrieval

Earlier we learned that amnesics demonstrate implicit learning of motor sequences (procedural knowledge) even when they cannot form explicit memories about the stimulus sequence. Amnesics provide powerful evidence that implicit learning need not be mediated by explicit knowledge about the material.

Scott Grafton, Eliot Hazeltine, and Ivry (1995) investigated the brain basis of procedural motor learning in normal subjects. They compared conditions in which the subjects learned motor sequences implicitly during dual-task conditions, which helped to prevent subjects from explicitly noticing and learning the sequence. PET conducted during the dual-task condition demonstrated activation of the motor cortex and the supplementary motor area of the left hemisphere, and the putamen in the basal ganglia bilaterally. Also activated were the rostral prefrontal cortex and parietal cortex. Therefore, when subjects were implicitly learning the task, brain areas that control limb movements were activated. When the distracting auditory task was removed, the right dorsolateral prefrontal cortex, right pre motor cortex, right putamen, and parieto-occipital cortex were activated bilaterally.

3.6.4 Perceptual Priming and Implicit and Explicit Memory

Daniel Schacter and his colleagues (1996) at Harvard University investigated the neural bases of perceptual priming (implicit learning) in a PET study. The scanning was performed only during the task. Subjects manifested implicit priming behaviourally. No activations or deactivations were noted in the hippocampus, but blood flow in the bilateral occipital cortex, (area 19) decreased (Figure 1.3.3). The hippocampus was not activated, then, even though implicit perceptual priming was obtained.

The conclusions from this and other studies are that implicit and explicit retrieval of information is subserved by separate brain systems. Together with the face encoding data Haxby and colleagues obtained by PET, and animal and human lesion data, a reasonable conclusion is that the hippocampus encodes new

information but also retrieves recent information when explicit recollection is involved. Perhaps more interestingly, deactivation of the visual cortex for previously seen words is a correlate of perceptual priming.

In summary, neuroimaging studies have demonstrated patterns of neuronal activation that are consistent with memory systems derived from cognitive research, studies in human amnesics, and animal models. Neuroimaging also has provided some notable new findings in the cognitive neuroscience of memory, including, for example, the hemispheric asymmetries in encoding and retrieval.

3.7 CELLULAR BASES OF LEARNING AND MEMORY

How does the activity of different brain regions change as memories are formed? Most models of the cellular bases of memory hold that it is the result of changes in the strength of synaptic interactions among neurons in neural networks. How would synaptic strength be altered to enable learning and memory? Neil Carlson (1994) described some basic physiological mechanisms for learning new information.

One basic mechanism is *Hebb's law*, named after the man who posited it, Canadian psychologist Donald Hebb, in 1949. Hebb's rule states that if a synapse between two neurons is repeatedly activated at about the same time the postsynaptic neuron fires, the structure or the chemistry of neuron changes and the synapse will be strengthened—this is known as *Hebbian learning*. A more general, and more complex, mechanism is called *long-term potentiation (LTP)*. In this process, neural circuits in the hippocampus that are subjected to repeated and intense electrical stimulation develop hippocampal cells that become more sensitive to stimuli.

That an excitatory input and postsynaptic depolarisation are needed to produce LTP is explained by the properties of the doubly gated *N-methyl-D-aspartate (NMDA) receptor* located on the dendritic spines of postsynaptic neurons that show LTP. Glutamate is the major excitatory transmitter in the hippocampus, and it can bind with NMDA and non-NMDA receptors. When 2-amino-5-phosphonopentanoate (AP5) is introduced to neurons, NMDA receptors are chemically blocked and LTP induction is prevented. But the AP5 treatment does not produce any effect on previously established LTP in these cells.

Therefore, NMDA receptors are central to producing LTP but not maintaining it. It turns out that maintenance of LTP may depend on the non-NMDA receptors.

Long-Term Potentiation and Memory Performance - This effect of enhanced response can last for weeks or even longer, suggesting to many that this could be a mechanism for long-term learning and retention (Baddeley, 1993).

Disrupting the process of long-term potentiation (say, through different drugs) also disrupts learning and remembering. Chemically blocking LTP in the hippocampus of normal mice impairs their ability to demonstrate normal place learning; thus, blocking LTP prevents normal spatial memory. In a similar way, genetic manipulations that block the cascade of molecular triggers for LTP also impair spatial learning.

These experiments provide strong evidence of impairing spatial memory by blocking NMDA receptors and preventing LTP. Moreover, we are rapidly developing a very clear understanding of the molecular processes that support synaptic plasticity, and thus learning and memory in the brain.

3.8 LET US SUM UP

The ability to acquire new information and retain it over time defines learning and memory. Cognitive theory and neuroscientific evidence argue that memory is supported by multiple cognitive and neural systems. These systems support different aspects of memory, and their distinctions in quality can be readily identified. Sensory registration, perceptual representation, working memory, procedural memory, semantic memory, and episodic memory all represent systems or subsystems for learning and memory. The brain structures that support various memory processes differ, depending on the type of information to be retained and how it is encoded and retrieved.

Despite the intriguing results from neuropsychological studies, we are far from having a complete picture of how the brain instantiates all, or even many, memory phenomenon. It is not clear which aspects of memory are localised in one place in the brain and which are distributed across different cortical regions. Tulving pointed that neuroscientists today reject the idea of studying memory as though it were a single process. Instead, they are likely to look for neurological underpinnings at a more precise level – at such processes as encoding or retrieval. The latest neuroimaging techniques clearly will continue to provide invaluable information about human memory and its neural substrates in the healthy human in the years to come.

3.9 UNIT END QUESTIONS

- 1) Summarize the findings of neuropsychological research on localising memory in the brain.
- 2) Compare and contrast the human and animal models of the study of neural basis of memory.
- 3) What exactly do findings from memory studies with amnesic patients tell us about the way memory operates in nonamnesic people?
- 4) Imagine what it would be like to recover from one of the forms of amnesia. Describe your impressions of and reactions to your newly recovered memory abilities.
- 5) How would you design an experiment to study the neural process of semantic memory by functional MRI technique?
- 6) Patient H.M. and others with damage to the medial temporal lobe develop amnesia. What form of amnesia do they develop, and what information can they retain, and what does this tell us about how memories are encoded in the brain?

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UNIT 4 MODELS OF INFORMATION PROCESSING

“Information is a source of learning. But unless it is organised, processed, and available to the right people in a format for decision making, it is a burden, not a benefit.”

– William Pollard

Structure

- 4.0 Introduction
- 4.1 Objectives
- 4.2 Waugh and Norman’s Model of Primary and Secondary Memory
- 4.3 Atkinson and Shiffrin’s the Stage Model
- 4.4 Level of Recall
- 4.5 Levels of Processing: Craik and Lockhart
- 4.6 Self Reference Effect
- 4.7 A Connectionist Model of Memory: Rumelhart and McClelland
- 4.8 Let Us Sum Up
- 4.9 Unit End Questions
- 4.10 Suggested Readings and References

4.0 INTRODUCTION

Cognition as a psychological area of study goes far beyond simply the taking in and retrieving information. Neisser (1967), one of the most influential researchers in cognition, defined it as the study of how people encode, structure, store, retrieve, use or otherwise learn knowledge. The information processing approach to human cognition remains very popular in the field of psychology.

Information processing is the change (processing) of information in any manner detectable by an observer. Within the field of cognitive psychology, information processing is an approach to the goal of understanding human thinking. It arose in the 1940s and 1950s. The essence of the approach is to see cognition as being essentially computational in nature, with *mind* being the *software* and the brain being the *hardware*.

One of the primary areas of cognition studied by researches is memory. By the 1960s research in memory had reached a high state of activity, and it was about this time that some formalised comprehensive theories of memory were beginning to be formulated. There are many hypotheses and suggestions as to how this integration occurs, and many new theories have built upon established beliefs in this area. Currently, there is widespread consensus on several aspects of information processing; however, there are many dissensions in reference to specifics on how the brain actually codes or manipulates information as it is stored in memory. This section considers a few of the more viable memory theories of that time.

4.1 OBJECTIVES

After reading this unit, you will be able to:

- define information processing approach;
- discussing the various models of information processing;
- explain levels of recall; and
- describe levels of processing.

4.2 WAUGH AND NORMAN'S MODEL OF PRIMARY AND SECONDARY MEMORY

The first modern behavioural model to travel down memory lane, and one whose concept of primary memory has served as a departure point for most modern theories, was developed by Waugh and Norman (1965). The theory is dualistic; *primary memory* (PM), a short-term storage system, is conceptualised as being independent of *secondary memory* (SM), a longer-term storage system. Waugh and Norman borrowed freely from William James's dichotomy of primary and secondary memory and illustrated their theory by means of the model shown in Figure below, which encouraged the memory metaphor of boxes in the head that soon proliferated in the literature of cognitive psychology.

What Waugh and Norman did that James never attempted was to quantify properties of primary memory. This short-term storage system was taken to have very limited capacity, so that loss of information from it was postulated to occur not as a simple function of time but (once the storage capacity was exhausted) by displacement of old items by new ones. PM could be conceptualised as a storage compartment much like a vertical file, in which information is stored in a slot or, if all the slots are filled, displaces an item occupying one of the slots.

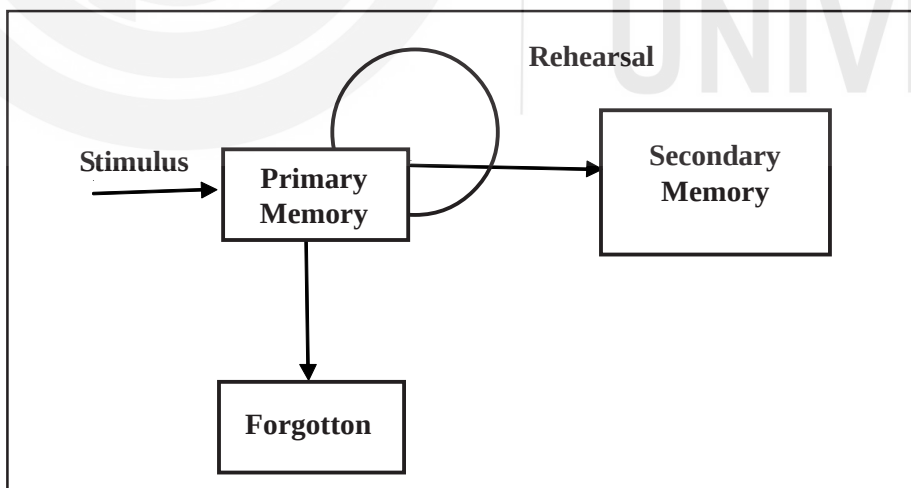


Fig. 1.4.1: Model of Primary and Secondary Memory (Adapted from Waugh and Norman (1965))

Waugh and Norman traced the fate of items in PM (primary memory) by using lists of sixteen digits, that were read to subjects at the rate of one digit per second or four digits per second. The purpose of presenting digits every second or quarter second was to determine whether forgetting was a function of decay (presumed to be due to time) or interference in PM.

If forgetting was a function of decay, then less recall could be expected with the slower rate (one digit per second); if forgetting was a function of interference in PM, then no difference in recall could be expected according to the presentation rate. The same amount of information is presented at both presentation rates, which, by Waugh and Norman's logic, allows the same time for decay to occur. It might be argued that even at one item per second, subjects would allow extra experimental information to enter their PM, but later experimentation (Norman, 1966) in which presentation rates varied from one to ten digits (for a given period), yielded data consistent with a rate of forgetting expected from the original model. The rate of forgetting for the two presentation rates is similar. Interference seems to be a greater factor than decay in forgetting in PM.

Waugh and Norman's system makes good sense. PM holds verbal information and is available for verbatim recall; this is true in our ordinary conversation. We can recall that last part of a sentence we have just heard with complete accuracy, even if we were barely paying attention to what was said. However, to recall the same information sometime later is impossible unless we rehearse it, which makes it available through SM.

4.3 ATKINSON AND SHIFFRIN'S THE STAGE MODEL

Traditionally, the most widely used model of information processing is the stage theory model, based on the work of Atkinson and Shiffrin (1968). The key elements of this model are that it views learning and memory as discontinuous and multi-staged. It is hypothesised that as new information is taken in, it is in some way manipulated before it is stored. The stage theory model, as shown in Figure 1.4.2, recognises three types or stages of memory: sensory memory, short-term or working memory, and long-term memory.

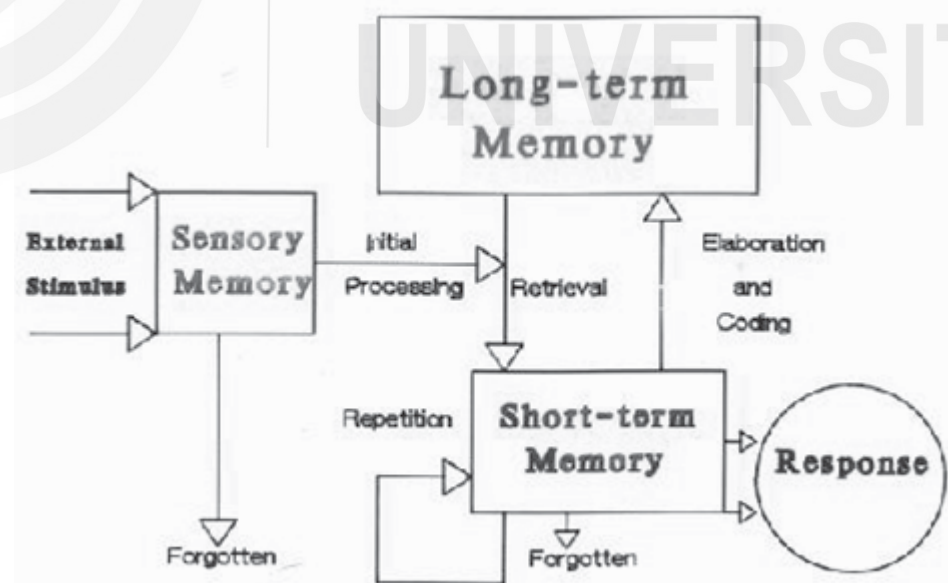


Fig. 1.4.2: A stage model of memory (Adapted from Atkinson and Shiffrin 1969)

In the Atkinson-Shiffrin model, memory starts with a sensory input from the environment. This input is held for a very brief time – several seconds at most – in a *sensory register* associated with the sensory channels (vision, hearing, touch, and so forth). This occurs in as little as $\frac{1}{2}$ second for visual stimuli (Sperling, 1960),

and about 4 or 5 seconds for auditory stimuli (Darwin et al., 1972). The transfer of new information quickly to the next stage of processing is of critical importance, and sensory memory acts as a portal for all information that is to become part of memory. There are many ways to ensure transfer and many methods for facilitating that transfer. To this end, attention and automaticity are the two major influences on sensory memory, and much work has been done to understand the impact of each on information processing.

Information that is attended to and recognised in the sensory register may be passed on to second stage of information processing, i.e. *short-term memory (STM)* or *working memory*, where it is held for perhaps 20 or 30 seconds. This stage is often viewed as active or conscious memory because it is the part of memory that is being actively processed while new information is being taken in. Some of the information reaching short-term memory is processed by being rehearsed – that is, by having attention focused on it, perhaps by being repeated over and over (maintenance rehearsal), or perhaps by being processed in some other way that will link it up with other information already stored in memory (elaborate rehearsal). Generally 5 + 2 number of units can be processed at any given time in STM.

Information that is rehearsed may then be passed along to *long-term memory (LTM)*; information not so processed is lost. When items of information are placed in long-term memory, they are organised into categories, where they may reside for days, months, years, or for a lifetime. When you remember something, a representation of the item is withdrawn, or *retrieved*, from long-term memory.

Organisations of long-term memory - Each of the memory unit or structures represented in the mind is distinct and serves a different operational function. However, it is evident that some type of very specialised categorisation system exists within the human mind. One of the first to make this idea explicit was Bruner (as cited in Anderson, 1998). “Based upon the idea of categorisation, Bruner’s theory states ‘To perceive is to categorise, to conceptualise is to categorise, to learn is to form categories, to make decisions is to categorise’”.

Tulving (1972) was the first to distinguish between *episodic* and *semantic* memory. “Episodic memories are those which give a subject the sense of remembering the actual situation, or event” (Eliasmith, 2001). Episodic memory’s store is centered on personal experience and specific events. It is entirely circumstantial and it is not generally used for the processing of new information except as a sort of backdrop. *Semantic memory*, in contrast, deals with general, abstract information and can be recalled independently of how it was learned. It is semantic memory that is the central focus of most current study because it houses the concepts, strategies and other structures that are typically used for encoding new information. Most researchers now combine these two in a broader category labeled declarative.

Other researchers have identified additional organisational types. For example, Abbott lists *declarative* and *procedural* while Huitt (2000), citing the work of Paivio (1971, 1986) adds *imagery* to this list. However, Pylyshyn (2002) states that imagery is not a distinct organisational structure, but follows the rules that apply to semantic and episodic memory. Abbott (2002) and Huitt (2000) define *declarative memory* as that which can be talked about or verbalised. It is, then,

the sum of stored information that can be readily retrieved and put into words in conscious thought and sharing. As previously stated, declarative memory can be subdivided into both semantic and episodic memories. *Procedural memory* can be thought of as “how to” knowledge (Huitt, 2000). It is the type of long-term memory sometimes associated with information that has reached a state of automaticity, but it not limited to this. This type of memory is defined in terms of learned skills and the ability to recall instruction-like memory. Paivio (1971, 1986) describes *imagery* as the memory structure for collecting and storing information related to pictures. It captures information much like a photograph and can be extremely useful for context and visual presentation of information.

Information Processing in Three Stage Model - Atkinson and Shiffrin make an important distinction between the concepts of memory and memory stores; they use the term *memory* to refer to the data being retained, while store refers to the structural component that contains the information. Simply indicating how long an item has been retained does not necessarily reveal where it is located in the structure of memory.

Information processing from one store to another is largely controlled by the subject. Information briefly held in the sensory register is scanned by the subject, and selected information is introduced into the STS. Transfer of information from the STS was regarded as capable of taking place so long as it was held there. Atkinson and Shiffrin postulated that information might enter the long-term store directly from the sensory register.

4.4 LEVEL OF RECALL

In a report by P. I. Zinchenko (1962, 1981), a Russian psychologist, the matter of how a subject interacts with the material to be learned and committed to memory was introduced. The basic notion was that words encoded by deep means would be retained in incidental memory better than if encoded by other, superficial means. Thus the memorability of words was profoundly influenced by the goal of the subject at the time the material was presented. Different goals were thought to activate different systems of connections because subjects have different orientations toward the material.

The thesis was tested in an experiment in which subjects were given ten series of four words. The first word was to be connected to one of the other words, but the instructions varied for each of three groups. An example of a series is *HOUSE—WINDOW—BUILDING—FISH*. In the first condition the subjects were asked to identify the word whose meaning was different from the first word (*HOUSE—FISH*). In a second condition subjects were asked to make a concrete connection between the first word and one of the other words [*HOUSE—WINDOW*]. In the third condition the subjects were asked to make a “logical” connection between the first word and one of the other three words [*HOUSE—BUILDING*].

Zinchenko thought that by altering the instructions the subjects would not only have different goals toward the material but also be required to examine each item for meaning. After a brief interrupting task, the subjects were asked to recall the items. In the condition in which subjects formed logical connections between the first word and another word, recall of the target word occurred with greater frequency than the other conditions. Recall of the concrete relationship words was greater than the no-meaning condition.

Thus the level of recall (LOR), as Zinchenko called it, is determined by the goal of an action. In the experiment cited, we can see that when subjects were given a learning set, or instructions to process material at different levels (to use contemporary jargon), recall of the material was affected greatly. Because the original paper was published in Russian and not widely distributed, it has not been incorporated into the larger framework of memory models. Nevertheless, as we shall see, the experiment presented by Zinchenko, because of its theoretical importance to the concept of levels of processing, which has had a profound influence on cognitive psychology, has important consequences for our conceptualisation of human memory.

4.5 LEVELS OF PROCESSING: CRAIK AND LOCKHART

It is likely that progress in the early stages of scientific development is made more by reaction and counterreaction than by the discovery of great immutable truths. Craik and Lockhart's (1972) *levels-of-processing (LOP) model*, as a reaction against the boxes-in-the-head scheme of memory, is consistent with that view. They take the position that data can be better described by a concept of memory based on levels of processing. The general idea is that incoming stimuli are subjected to a series of analyses starting with shallow sensory analysis and proceeding to deeper, more complex, abstract, and semantic analyses.

Whether a stimulus is processed at a shallow or deep stage depends on the nature of the stimulus and the time available for processing. An item processed at a deep level is less likely to be forgotten than one processed at a shallow level. At the earliest level, incoming stimuli are subjected to sensory and featural analyses; at a deeper level, the item may be recognised by means of pattern recognition and extraction of meaning; at a still deeper level, it may engage the subject's long-term associations.

With deeper processing a greater degree of semantic or cognitive analysis is undertaken. Consider word recognition, for example. At the preliminary stages, the visual configuration may be analysed according to such physical or sensory features as lines and angles. Later stages are concerned with matching the stimuli with stored information—for example, recognition that one of the letters corresponds to the pattern identified as A. At the highest level, the recognised pattern “may trigger associations, images or stories on the basis of the subject's past experience with the word” (Craik & Lockhart, 1972).

The significant issue, in Craik and Lockhart's view, is that we are capable of perceiving at meaningful levels *before* we analyse information at a more primitive level. Thus, levels of processing are more a “spread” of processing, with highly familiar, meaningful stimuli more likely to be processed at a deeper level than less meaningful stimuli.

That we can perceive at a deeper level before analysing at a shallow level casts grave doubts on the original levels-of-processing formulation. Perhaps we are dealing simply with different types of processing, with the types not following any constant sequence. If all types are equally accessible to the incoming stimulus, then the notion of levels could be replaced by a system that drops the notion of

levels or depth but retains some of Craik and Lockhart's ideas about rehearsal and about the formation of memory traces.

A model that is closer to their original idea is shown in Figure 1.4.3. This figure depicts the memory activation involved in proofreading a passage as contrasted with that involved in reading the same passage for the gist of the material. Proofreading, that is, looking at the surface of the passage, involves elaborate shallow processing and minimal semantic processing.

Reading for gist, that is, trying to get the essential points, involves minimal shallow processing, or "maintenance rehearsal" (held in memory without elaboration), but elaborate semantic processing. Another example of this latter kind of memory activity would be a typist who concentrates on responding to letter sequences but has very little understanding of the material being typed.

As a result of some studies (Craik & Watkins, 1973; and Lockhart, Craik, & Jacoby, 1975), the idea that stimuli are always processed through an unvarying sequence of stages was abandoned, while the general principle that some sensory processing must precede semantic analysis was retained.

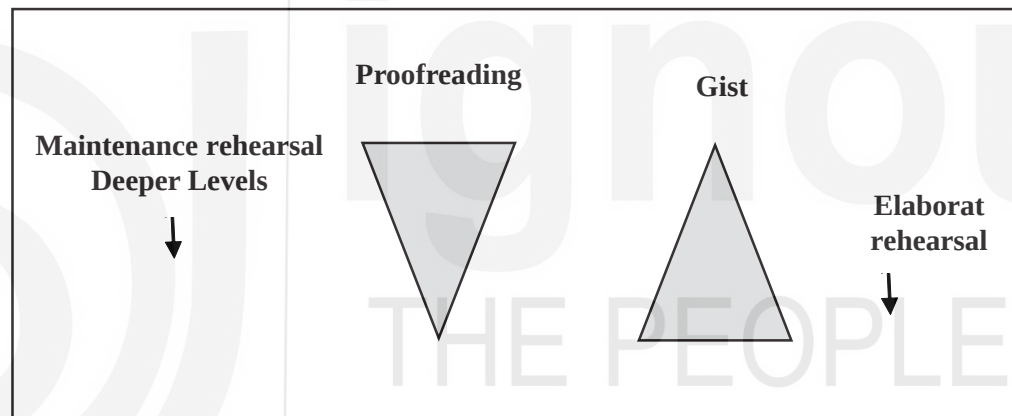


Fig. 1.4.3: Memory activation in two kind of reading. (Adapted from Solso, 2006)

Levels of Processing versus Information Processing. Information-processing models of memory have generally stressed structural components (for example, sensory store, STM, and LTM) dealing with processing (for example, attention, coding, rehearsal, transformation of information, and forgetting) as operations that are tied (sometimes uniquely) to the structural components. However, another approach is to postulate process and then to formulate a memory system in terms of these operations. Craik and Lockhart have taken just such a position, and their implicit criticism of the information processing model (along with Neisser, 1976) suggests that it is falling on hard times.

Where information-processing models of memory stress the sequence of stages through which information is moved and processed, this alternate viewpoint argues that memory traces are formed as a by-product of perceptual processing. Thus, the durability of memory is conceptualised as a function of the depth of processing. Information that is not given full attention and is analysed only to a shallow level is soon forgotten; information that is deeply processed—attended to, fully analysed and enriched by associations or images—is long lasting. The levels-of-processing model is not free of criticism (see Craik & Tulving, 1975; and Baddeley, 1978). The criticism includes that (1) it seems to say little more than that meaningful events are well remembered, a mundane conclusion; (2) it

is vague and generally untestable; and (3) it is circular in that any events that are well remembered are designated “deeply processed,” with no objective and independent index of depth available.

One clear difference between the boxes-in-the-head theory (Waugh and Norman, and Atkinson and Shiffrin) and the levels-of-processing theory (Craik and Lockhart) is their respective notions concerning rehearsal. In the former, rehearsal, or repetition, of information in STM serves the function of transferring it to a longer-lasting memory store; in the latter, rehearsal is conceptualised as either maintaining information at one level of analysis or elaborating information by processing it to a deeper level. The first type, maintenance rehearsal, will not lead to better retention.

Craik and Tulving (1975) tested the idea that words that are deeply processed should be recalled better than those that are less so. They did this by having subjects simply rate words as to their structural, phonemic, or semantic aspects. Craik and Tulving measured both the time to make a decision and recognition of the rated words. The data obtained are interpreted as showing that (1) deeper processing takes longer to accomplish and (2) recognition of encoded words increases as a function of the level to which they are processed, with those words engaging semantic aspects better recognised than those engaging only the phonological or structural aspects. Using slightly different tasks, D’Agostino, O’Neill, and Paivio (1977); Klein and Saltz (1976); and Schulman (1974) obtained similar results.

4.6 SELF REFERENCE EFFECT

New light was shed on the levels-of-processing concept when Rogers, Kuiper, and Kirker [1977] showed that self-reference is a powerful method variable. Using a method similar to that of Craik and Tulving (1975), they asked subjects to evaluate a list of forty adjectives on one of four tasks hypothesised to vary in depth, or semantic richness. Included were structural, phonemic, semantic, and self-reference tasks.

As in the Craik and Tulving study, it was assumed that words more deeply coded during rating should be recalled better than those words with shallow coding. After the subjects rated the words, they were asked to free-recall as many of the words they had rated as possible. Recall was poorest for words rated structurally and ascended through those phonemically rated and semantically rated. Self-reference words were recalled best.

The Narcissistic Trait Modifications of the original experiment have been conducted in several laboratories with the results being about the same. Some have argued that self-reference tasks are stored in some special memory system.

Certainly, if you are asked to evaluate a personality trait as being self-descriptive, such as greedy, loving, or angry, you are engaging a very powerful self-schema, an organised system of internal attributes that is constellated around the topic of “I, me, mine.” We also call this the narcissistic trait. Since we all know a great deal about ourselves (and are emotionally, if not intellectually, deeply invested in ourselves) we have a rich and elaborate internal network available for storing self-information. Because of these complex internal self structures we can more

easily organise new information as it might refer to ourselves than other, more mundane information (see Bellezza 1992 for several important studies on this theme). Whether or not these self-rating memories are stored in different parts of the brain remains a question, but it is a good hunch that plenty of precious brain space is given over to the narcissistic trait.

4.7 A CONNECTIONIST (PARALLEL DISTRIBUTED PROCESSING) MODEL OF MEMORY: RUMELHART AND MCCLELLAND

Many people have been associated with this model of human cognition, but David Rumelhart and James McClelland have done the most to formalise the theory.

Essentially, the model is neutrally inspired, concerned with the kind of processing mechanism that is the human mind. Is it a type of von Neumann computer – a Johniac – in which information is processed in sequential steps? Alternatively, might the human mind process information in a massively distributed, mutually interactive parallel system in which various activities are carried out simultaneously through excitation and/or inhibition of neural cells? PDPers opt for latter explanation.

“These [PDP] models assume that information processing takes place through the interactions of a large number of simple processing elements called units, each sending excitatory and inhibitory signals to other units” (McClelland, Rumelhart, & Hinton, 1986). These units may stand for possible guesses about letters in a string of words or notes on a score. In other situations, the units may stand for possible goals and actions, such as reading a particular letter or playing a specific note. Proponents suggest that PDP models are concerned with the description of the internal structure of larger units of cognitive activity, such as reading, perceiving, processing sentences, and so on.

The connectionist (or PDP) model attempts to describe memory from the even finer-grained analysis of processing units, which resemble neurons. Furthermore, the connectionist model is based on the development of laws that govern the representation of knowledge in memory. One additional feature of the PDP model of memory is that it is not just a model of memory; it is also a model for action and the representation of knowledge.

A fundamental assumption of the PDP model is that mental processes take place through a system of highly interconnected units, which take on activation values and communicate with other units. Units are simple processing elements that stand for possible hypotheses about the nature of things, such as letters in a display, the rules that govern syntax, and goals or actions (for example, the goal of typing a letter on a key board or playing a note on the piano). Units can be compared to atoms, in that both are building blocks for more complete structures and combine with others of their kind to form larger networks. A neuron in the brain is a type of unit that combines with other neurons in a parallel processing mode to form larger systems.

Units are organised into modules, much as atoms are organised into molecules. The number of units per module range from thousands to millions. Each unit

receives information from other modules and, after processing, passes information to other modules. In this model, information is received, is permeated throughout the model, and leaves traces behind when it has passed through. These traces change in the strength (sometimes called weight) of the connections between individual units in the model.

A memory trace, such as a friend's name, may be distributed over many different connections. The storage of information (for example, friend's name) is thought to be content addressable—that is, we can access the information in memory on the basis of its attributes. You can recall your friend's name if I show you a picture of him, tell you where he lives, or describe what he does. All of these attributes may be used to access the name in memory. Of course, some cues are better than others.

Even though the theory is abstract, it touches real-life activities. To continue with the example of your friend's name, suppose I ask, "What is the name of the man you play tennis with?" Such an inquiry gives at least two content-addressable cues: man and tennis partner. If you play tennis with only one man (and you know his name), then the answer should be easy. If you have many partners who are men, then the answer may be impossible.

Additional information (for example, the man with the beard, the left handed player, the guy with red tennis shorts, the dude with the rocketlike serve, the chap with the Boston terrier, and so forth) may easily focus the search. You can imagine how very narrow the search would be if all of these attributes were associated with only one person: the man you play tennis with has a beard, is left-handed, wears red tennis shorts, has a hot serve, and has a terrier.

In real life, each of these attributes may be associated with more than one person. You may know several people who have a hot serve or have a beard. If that is the case, it is possible to recall names other than the intended one. However, if the categories are specific and mutually exclusive, retrieval is likely to be accurate. How can a PDP modular concept of memory keep these interfering components from running into each other?

According to this model, information is represented in memory in terms of numerous connections with other units. If an attribute is part of a number of different memories and is activated (for example, What was your friend's name ...?), then it will tend to excite all the memories in which the attribute is a part. One way interfering components are kept from overrunning the system is to conceptualise the relationship between units as being subject to inhibitory laws. Thus, when we identify the person you play tennis with as a man, in theory we inhibit all searches for people who are women. When we add that he has a Boston terrier, then we do not search for the names of people with whom you do not play tennis and who do not own a Boston terrier.

Consider the following example of prototype learning, suggested by McClelland and Rumelhart (1986). A small boy sees many different dogs, each only once and each with a different name. All the dogs have slightly different features but can be considered a variation of the prototype dog, the epitome of "dogness." The boy forms a memory for a prototypical dog on the basis of experience with exemplar dogs. As in the case of faces, the boy is likely to recognise the prototype dog as a dog, even if he has never seen it. Of course, the boy is not likely to

remember the names of each of the individual dogs, though the most recently seen dog may still be in memory.

The rationale offered by the connectionist model for prototype formation in the case of the boy and his (prototype) dog is that each time the boy sees a dog, a visual pattern of activation is produced over several of the units in the module. In contrast, the name of the dog produces a reduced pattern of activation. The combined activation of all exemplar dogs sums to the prototype dog, which may be the stable memory representation. Thus, the model, more detailed than presented here, seems to account for this form of memory quite nicely.

The connectionist model of memory has won many disciples in the past few years. Its popularity is due in part to its elegant mathematical models, its relationship to neural networks, and its flexibility in accounting for diverse forms of memories.

4.8 LET US SUM UP

In summary, there are many different theories and models of information processing that focus on different aspects of perceiving, remembering, and reasoning. There are many constant themes of information processing regardless of the specific theory to which one subscribes. Almost all ideas related to how information becomes stored in memory agree that the learner more deeply and meaningfully processes information that is presented in a context-rich manner. One of the most important agreements is that elaboration is a key to permanently storing information in a way that facilitates its quick retrieval when it is needed. Most theories hold that the mind contains some type of framework into which new information is placed. This structure is multi-leveled and has varying degrees of specificity. New information can be matched with, compared to, contrasted to, joined with, or modified to fit with existing structures. The formation of and continual building of these structures, then, is critical in order to process information. This in-place structural system allows for differing levels of complexity of information processing.

4.9 UNIT END QUESTIONS

- 1) Describe the Atkinson-Shiffrin model of information processing in detail.
- 2) Compare information processing and level of processing models of memory.
- 3) How does a connectionist (PDP) model handle memory?
- 4) What is meant by level of recall, level of processing, and self-reference effect?
- 5) What are the basic principles and models of information processing?
- 6) How does organisation in long-term memory take place?
- 7) Design an experiment to compare the maintenance (shallow) and elaborate level of information processing

4.10 SUGGESTED READINGS AND REFERENCES

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UNIT 1 THEORIES OF INTELLIGENCE (G AND S FACTORS AND THE MODEL OF JP DAS)

Structure

- 1.0 Introduction
- 1.1 Objectives
- 1.2 The Nature of Intelligence
 - 1.2.1 Theoretical Definitions of Intelligence
 - 1.2.2 Operational Definition of Intelligence
 - 1.2.3 Historical Perspective on Individual Differences and Human Abilities
- 1.3 Spearman's Two-Factor Theory of Intelligence
 - 1.3.1 Critical Appraisal of Two-Factor Theory
 - 1.3.1.1 Thorndike's Theory
 - 1.3.1.2 Thomson's Theory
 - 1.3.1.3 Thurstone's Theory
- 1.4 Das, Nagliery and Kirby's PASS Theory
 - 1.4.1 Critical Appraisal of the PASS Theory
- 1.5 Let Us Sum Up
- 1.6 Unit End Questions
- 1.7 Suggested Readings and References

1.0 INTRODUCTION

Right from the dawn of civilisation man has often wondered about individual differences in abilities, yet it was not until the third quarter of the nineteenth century that efforts could be made about understanding its complex nature. Intelligence is a broad term that is employed by layman to denote the presence of such qualities as alertness, quickness of mind, level of one's academic success, status in an occupation, or the acquisition of an eminence in a particular field of endeavour and so on. In this unit we will deal with the nature and meaning of intelligence. We will also discuss some of the most important theoretical models of intelligence so as to understand its nature. We will begin with some definitions to bring home the point that even among the psychologists there is a lack of unanimity about this term. We will also briefly outline a historical perspective on individual differences and human abilities. Following this there will be a discussion on the Spearman's Two factor theory consisting of G and S factors, and a critical appraisal of the theory. We would also be dealing with Thorndike's theory of intelligence and PASS theory of intelligence put forward by JP Das and colleagues.

1.1 OBJECTIVES

After reading this unit, you will be able to:

- Define the term intelligence;
- Obtain a brief overview of individual differences and intelligence;

- Discuss Spearman's Two-Factor theory of intelligence;
- Make a critical appraisal of Two-Factor theory;
- Describe J. P. Das, Nagliery, and Kirby's PASS theory of intelligence; and
- Analyse the PASS theory.

1.2 THE NATURE OF INTELLIGENCE

Intelligence is hard to define. In the Indian systems of thought *buddhi* (intellect)—defined as *nischayatmikabuddhih* (decision maker) is described as an inner instrument (*antahkarana*), which possesses wisdom, prudence, emotion, societal values, and relations. In our common parlance when people speak of intelligence, they nod knowingly as if they all share a common definition. However, their understanding of the phenomenon of intelligence may widely vary. For some quickness of answering a question might reflect intelligence, while for others leading a successful life might be due to one's intelligence. Psychologists, too, differ in their definitions of intelligence. We all know what we mean when we use this term, but we find it terribly difficult to precisely define it.

1.2.1 Theoretical Definitions of Intelligence

Intelligence has been defined as the sum total of everything you know, as the ability to learn or profit from experience, as the ability to solve problems or as the ability to cope with the demands of the environment. Indeed there is nothing wrong with any of these definitions. The problem arises when we try to search for a definition that seems to say it all precisely. We have been using "intelligence" as a general label for so many cognitive abilities that it defies a specific definition. In 1921, a symposium was organised to define intelligence. Thirteen psychologists specialising in the area of intellectual assessment considered the definitional aspects of intelligence. The symposium proceedings, published in a special issue of the *Journal of Educational Psychology*, revealed that the experts had thirteen different views on the nature of intelligence. Some of the definitions given by experts are given below:

"...intelligence, that is to say, reasoning, judgment, memory, and the power of abstraction" (Binet 1890, cited in Sattler, 1988, p. 45)

"Intelligence is a general capacity of the individual consciously to adjust his thinking to new requirements" (Stern, 1914)

"An individual is intelligent in proportion as he is able to carry on abstract thinking" (Terman, 1921, p. 128)

"Intelligence is the capacity of the organism to adjust itself to an increasingly complex environment" (Spearman, 1927)

In 1986, Sternberg and Determan found that twenty-four prominent scholars had twenty-four different definitions of intelligence. Sternberg (1997) has attempted a comparison of the two surveys. He has remarked that in the 1921 survey, the elements that appeared most often in the definitions were "(a) higher level abilities (such as abstract reasoning, mental representation, problem solving, and decision making), (b) ability to learn, and (c) adaptation to meet the demands of the environment. In the 1986 survey, the most common elements were (a) higher

level abilities, (b) that which is valued by culture, and (c) executive process” (Sternberg, 1997, p.1030).

Snyderman and Rothman (1987) have presented responses of over 1,000 experts that belonged to different disciplines such as psychology, sociology, education, and genetics. Of the thirteen descriptions rated by the respondents, there was nearly unanimous agreement that abstract reasoning, the capacity to acquire knowledge, and problem solving ability were important elements of intelligence.

Per cent of respondents showing agreement on thirteen descriptor elements of intelligence given by Snyderman and Rothman (1987) are given below:

Table Showing Responses of Experts on Thirteen Elements of Intelligence

Descriptor	% of Respondents Checking as Important
Abstract thinking or reasoning	99.3
Problem solving ability	97.7
Capacity to acquire knowledge	96.0
General knowledge	88.3
Memory	80.5
Adaptation to one’s environment	77.2
Mental speed	71.7
Linguistic competence	71.0
Mathematical competence	67.9
Creativity	59.6
Sensory acuity	24.4
Goal directedness	24.0
Achievement motivation	18.9

Source: Snyderman & Rothman (1987)

Most of the earlier definitions as well as recent ones include the elements that have been given above. We will mention a couple of recent definitions to support our statement.

“Intelligence, as a hypothetical construct, is the aggregate or global capacity of the individual to act purposefully, to think rationally and to deal effectively with his environment” (Wechsler, 1944). More recently, Wechsler (1975) defined intelligence as “the capacity of an individual to understand the world about him and his resourcefulness to cope with its challenges” (p.139).

“...a human intellectual competence must entail a set of skills of problem solving—enabling the individual to resolve genuine problems or difficulties that he or she encounters, and, when appropriate, to create an effective product—and must also entail the potential for finding or creating problems—thereby laying the groundwork for the acquisition of new knowledge.” (Gardner, 1983, pp. 60-61)

“Intelligence comprises the mental abilities necessary for adaptation to, as well as shaping and selection of, any environmental context.” (Sternberg, 1997, p.1030)

A common element of several of the definitions that we have quoted is adaptation, the ability to modify one’s behaviour to meet the environmental demands. A second common element is the ability to think abstractly using symbols. The ability to acquire new information or to learn through experience is similarly the third common element. However, it appears that the quest for a satisfactory definition of intelligence is an unending search.

1.2.2 Operational Definition of Intelligence

Observing the diversity of theoretical definitions in the 1921 survey, about which we discussed above, Boring (1923) operationally defined that “intelligence is what intelligence tests measure”. You may notice that this operational definition sidesteps the thorny conceptual problem of coming to grips with the “true” nature of intelligence; it does not solve it. Nonetheless it does what operational definitions are supposed to do—it gives us a definition we can start working with. Most intelligence tests have been constructed with the assumption that intelligence is some kind of general attribute, more or less of which exists in everyone and which determines how an individual will be able to deal with a problem situation. However, this sort of assumption is not supported by recent theoretical models of intelligence that we will discuss next.

1.2.3 Historical Perspective on Individual Differences and Human Abilities

It is extremely surprising that in spite of tremendous advances in mathematical sciences by the year 1800, systematic studies of human abilities were not undertaken until third quarter of the nineteenth century. Impressed by Charles Darwin’s *Origin of species*, his cousin Francis Galton devoted increasing attention toward measurement of anthropological and psychological phenomena. He coined the term *mental test* and invented the first psychological test methods to measure intelligence and ability. He founded the first test laboratory in London in 1882 at which visitors could take a battery of psychological tests on a fee-paying basis. Each visitor was tested on a variety of physical and sensory tests, including height, weight, breathing power, strength of pull, hearing, sight, and colour sense. Galton believed that psychological traits could also be inherited like physical characteristics. In statistics he made important contribution by developing and applying correlation method, which, at his guidance, was later continued by his student Karl Pearson, who eventually developed the product-moment correlation. Though his tests bear no resemblance to the advanced psychological tests, he definitely deserves to be credited with the title of Father of psychological testing and individual differences.

Alfred Binet’s early work on human abilities resembled the work of Galton. Binet’s work on intelligence testing took a practical turn during the opening years of the twentieth century, when he was commissioned by the French government to identify mentally deficient children in French schools. Faced with this problem, Binet, in collaboration with Theodore Simon, completed his first test in 1905. This test comprised a list of 30 problems concerning the child’s ability to understand and reason with the objects in the environment. The problems ranged in level of difficulty and the test was tried on a sample of 50 children.

This was a very important step in the testing of intelligence.

In 1908, a revision was made in which items were arranged in terms of age levels. The highest age level that a child could perform successfully was called his *mental age*. Later, William Stern (1914) suggested that this be divided by the chronological age for each child, which multiplied by 100 became the intelligence quotient, the IQ, as it has come to be known. The influence of Binet on the measurement of intelligence can hardly be overstated. All subsequent work on the measurement of intelligence is modeled after Binet's test.

Self Assessment Questions

1) How does a layman define intelligence?

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2) What were the common factors that emerged regarding the definition of intelligence in the 1921 symposium of thirteen experts?

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3) On which elements there is maximal agreement in the Snyderman and Rothman data on 1000 experts?

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4) How will you operationally define the phenomenon of intelligence?

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5) Present a brief account of individual differences.

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1.3 SPEARMAN'S TWO-FACTOR THEORY OF INTELLIGENCE

Charles Spearman published an epoch-making study in 1904, which indeed proved to be the crucial step toward quantitative testing of theories, as opposed to simple quantification or measurement. He used the techniques of correlational analysis and factor analysis, both of which had been developed earlier by Karl Pearson, in relation to the scores obtained by groups of children on various intelligence tests. His historical significance can be seen in the development of the factor analytical method and in its explicit use for the first time. It is with regard to such importance that Guilford (1954, p. 472) has stated: "No single event in the history of mental testing has proved to be of such momentous importance as Spearman's proposal of his famous two-factor theory in 1904."

Spearman was critical of Binet and Simon's (1905) practice of assembling a hodgepodge of problems for testing intelligence without first testing for the presence of a general factor or without weighing the problems in terms of their loadings on the general factor. He was concerned to test the theory that the obtained intercorrelations between various tests of intelligence were due entirely to a general intellectual factor "g". In addition to that, he also recognised specific factors, "s" factors, which were specific to particular tests. Eysenck (1972, pp. 1-2) has contended that "essentially his point was that under these conditions matrices of intercorrelations between tests should be of rank one; he did not use matrix algebra himself, but his formulas are the equivalent of more modern versions." Spearman (1927) elaborated and revised his work in *"The abilities of man."*

To understand his theory, let us assume that any correlation between two tests used by Spearman implies a factor common to both, plus two specific factors. Let the two tests be called a and b , the common factor " g ", and the two specific factors s_a and s_b , as shown in the diagram drawn by Guilford (1953), which are reproduced below in Fig. 1.1.

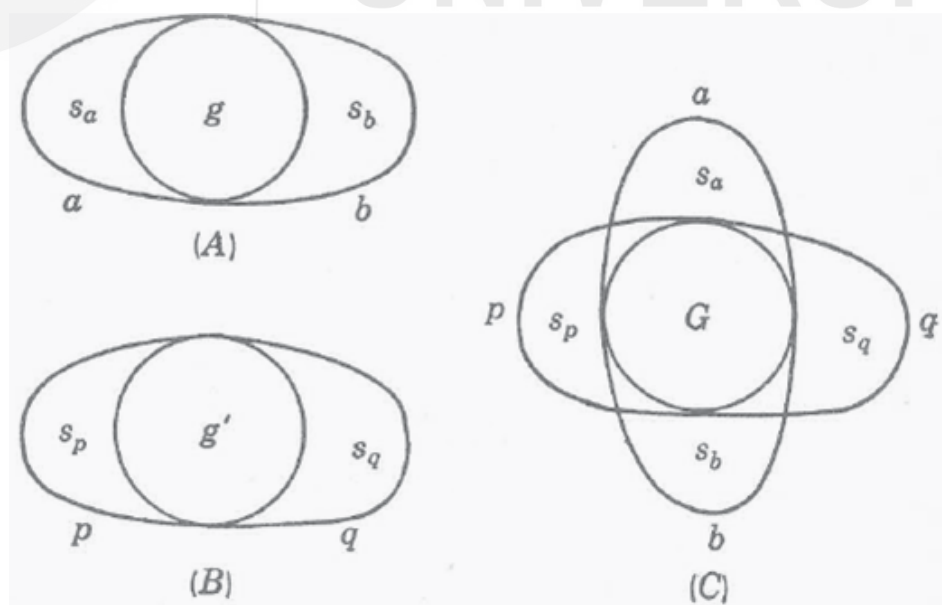


Fig.1.1: Graphical representation of Spearman's two factor theory

(Source: Guilford, 1953, p. 472)

In terms of the two-factor theory, we may regard that tests *a* and *b* are two measures of the common element “*g*”, with the two remainders *sa* and *sb*. Similarly, let *p* and *q* be two other tests with “*g*” as the common element as shown in the Figure above. For some experiments, Spearman (1904) reported the correlations between “*g*” and “*g*” to approximate a value of 1.00. This meant that “*g*” and “*g*” were practically identical. Spearman believed that all intellectual activity contained some element or factor in common. This “*g*”, or general factor, was postulated to be important in every mental act, although some acts were thought to depend upon it more than others. The difference between people in intelligence was a matter of how much “*g*” they possessed. Spearman called this general factor as “mental energy.”

Spearman’s analysis of intelligence was actually an interpretation of certain observations by using the method of *tetrad difference*. The correlation matrix, which he used for finding the criterion of proportionality and for calculating the tetrad difference, is given below:

Table Showing Intercorrelations of Subtests Reported by Spearman (1927)

Subtests	1	2	3	4	5	6	7
Analogies	...	.50	.49	.55	.49	.45	.45
Completion	.50	...	.54	.47	.50	.38	.34
Understanding paragraphs	.49	.54	...	.49	.39	.44	.35
Opposites	.55	.47	.49	...	.41	.32	.35
Instructions	.49	.28	.39	.41	...	.32	.40
Resemblances	.45	.38	.44	.32	.32	...	.35
Inferences	.48	.34	.35	.35	.40	.35	...

Source: Spearman (1927) *The abilities of man*. New York: Macmillan, (p.149)

Guilford (1953, pp. 473-474) has shown that for any correlation matrix the criterion of proportionality can be easily calculated, following which the tetrad difference between various subtests can also be found.

Let us understand what is tetrad difference? In recent years the quantity *F*, called the ‘tetrad-difference’, has become very important in psychological investigations as to the possible nature of the underlying causes of mental activities. If there are four such activities, and r_{13} , r_{24} , etc., the six correlation coefficients, (*F* is defined by the equation $F = r_{13}r_{24} - r_{14}r_{23}$. The value of *F*, in practice, approximates to zero.)

The tetrad difference thus in all cases comes to zero. The variation in measured intelligence that was not explainable in terms of this general factor or “*g*” was attributed by Spearman to specific factors or “*s*”. There were many different specific factors. All intellectual tasks require some amount of “*g*.” according to Spearman, the more highly the two functions were correlated, the more highly saturated they were with “*g*.” Tests that are thought to have high “*g*” loadings involve abstract reasoning, comprehension, and problem solving.

Graphic illustration of “*g*” and “*s*” can be made following Guilford (1953, pp. 474-475), which is reproduced below (Fig.2). In this Figure “Spearman’s “*g*” factor is shown as the large central circle and the specifics as small circles grouped

about G . Each ellipse stands for a mental test. The ellipses are permitted to overlap G to different extents in order to indicate the fact that some tests are more heavily “loaded” with G than others. The amount of correlation between any two tests is determined by the extent to which the two tests are loaded with G . Thus, tests a and b will have a relatively high correlation, since they have much in common in G . Tests a and c will be scarcely correlated at all, since both have small loadings with G .” (Guilford, 1953, pp. 474-475)

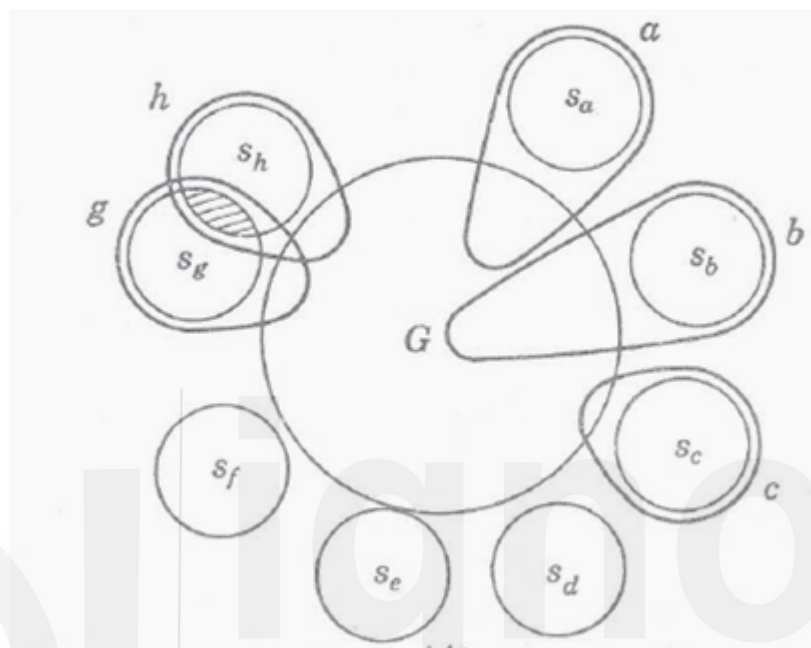


Fig. 1.2: Graphical representation of group factor in Spearman's two factor theory

(Source: Guilford, 1953, p. 475)

Inter correlation matrices prepared by Spearman and his students showed that some tests had something in common besides factor G . That meant that there were some correlations that were over and above that demanded by a single common factor G . Spearman at first attributed this to overlapping s factors. However, some tests may have a higher correlation than that attributable to G alone. Such an additional common factor became known as a *group factor*, which was found to play a role not only in two tests but also in a number of tests. “Among the group factors that Spearman and his associates came to recognise are verbal ability, numerical ability, and possible factors of mental speed, mechanical ability, attention, and imagination” (Guilford, 1953, p. 475).

Spearman's theories of intelligence are very stimulating and his contribution to the psychology of intelligence can be regarded important mainly for two major reasons.

- 1) First, he developed the mathematical models for studying “ g ” and for that purpose he laid the foundation of factor analysis. The logic and method of correlational analysis was afterward followed by other researchers for developing multi-factorial theories of intelligence.
- 2) Second major importance of Spearman's work is that it established a scholarly tradition in the investigation of human abilities.

According to Nunnally (1978, p. 508) “Spearman was concerned much more with *understanding* human abilities than with just measuring them. Spearman

had many interesting theories about *G*, its biological basis, the influence of culture, the interaction of *G* with manifestations of abilities in daily life, and the relation of *G* to speed, fatigue, and other variables.”

1.3.1 Critical Appraisal of Two-Factor Theory

Several criticisms were levelled against formulation of the two-factor theory. One of the standard criticisms of the factor analytic approach is that it was purely psychometric and failed to provide a cognitive theory. However, Sternberg and Frensch (1990) have convincingly argued that this criticism was misplaced.

Spearman (1923) proposed that intelligence depended on a number of qualitative principles of cognition, for example “the presenting of any character together with any relation tends to evoke immediately the knowing of the correlative character” (p.91).

According to M. W. Eysenck (1990) Spearman also described “five quantitative principles of cognition, which are relevant to intelligence: conative control, fatigue, mental energy, primordial potencies, and retentivity” (p. 192).

Jensen (1998) confirmed the existence of “*g*” by the method of confirmatory factor analysis.

Carroll (1993) also noted the presence of “*g*” at Stratum III in her hierarchical factor analysis. We will now attempt a critical appraisal of the two-factor theory and see how it has helped in the development of newer models of intelligence.

1.3.1.1 Thorndike’s Theory

One of the sharpest critics of Spearman’s two-factor theory was E. L. Thorndike (1926), who believed that the inter correlations studied by Spearman were too small to test the question of a common factor. He objected very strongly to the idea of the existence of a characteristic such as general intelligence. Instead of one kind of factor, he maintained that there are a large number of separate characteristics that make up intelligence.

He argued that instead of generality of intelligence, communality in the acts of people to perform intelligently needed to be looked into. According to Thorndike, the common element does not reside in the individual but in the nature of the tasks themselves. People differ in their ability to perform any specific act in terms of the level of difficulty they can manage. They also differ in the range or number of tasks they can or cannot perform.

For Thorndike, intelligence was more like a series of skills or talents and several or many tasks might call for the same kind of ability. According to him, the correlations between various tests are the result of the fact that the tests have features in common with each other even though they are called as measures of different aspects.

Thorndike’s contention that there is no general intelligence but very specific acts has, however, does not hold water in view of the fact that some tasks have so many elements in common that it is desirable to classify them into groups such as arithmetical reasoning, visual perception, word meaning, analogy, etc.

Thorndike has classified intellectual activity into three broad types: (i) social intelligence, (ii) concrete intelligence, and (iii) abstract intelligence. However, this is a classification of the type of tasks and not an analysis of mental organisation itself. One can notice that the discrepancy of point of view between Spearman and Thorndike is basically a theoretical one and the types that interested Thorndike are essentially the same as the measures which Spearman used in his correlation matrix.

1.3.1.2 Thomson's Theory

Among the other critics of Spearman, G. H. Thomson (1939) has argued that the inter correlations between tests are actually the result of common samplings of independent factors. As such if the tests incorporate many of these independent factors in common, i.e., the tests are all measuring some of the same factors, they will be highly inter correlated and it will appear that they are measuring one general factor “*g*.”

Thomson has accordingly proposed a sampling theory, which maintains that every test samples a certain range of elementary abilities; some with a wide range and some with a narrow range. The degree of correlation between any two tests depends upon the number of units of ability that they have in common.

According to Thomson, abilities combine in such a way that their correlations approach Spearman hierarchical order. Thomson believed in a “general ability” like Spearman’s “*g*”, but according to him it was not a basic entity; it was rather a constant combination of the ability elements.

In like manner, the group factors are combinations of more limited collections of ability elements, while specific factors are composed of elements that restrict their appearance to single tests.

Guilford (1953) has refuted Thomson’s contentions saying that “there seems to be little likelihood of demonstrating experimentally the existence of the elements hypothesized” (p.476).

1.3.1.3 Thurstone's Theory

L.L. Thurstone (1935) offered a new factor model in the nineteen thirties. Using improved techniques of statistical analysis, he came to vastly different conclusions from Spearman about nature of intelligence. Thurstone generalised Spearman’s methods and formulas, translated them into matrix algebra and carried out large-scale studies, using as many as fifty-seven tests on one group of subjects. On the basis of these studies he concluded that instead of Spearman’s “*g*” factor, seven primary abilities fitted the data much better.

Eysenck (1972) has given two reasons of this type of apparently conflicting findings. The first related to population sampled. Spearman had worked with random samples of the population (usually children), Thurstone worked only with students. The second related to the choice of tests: “Spearman has explicitly stated that tests should not be too similar to each other; if they were, then the “*s*” factors would overlap and cause additional correlations which would emerge as separate factors and disturb the unit rank of the matrix. Thurstone used groups of tests which were very similar, often almost identical, and consequently his study could certainly not be considered as a test of Spearman’s hypothesis” (Eysenck, 1972, p. 2).

Thurstone later on recognised the force of these points and incorporated them in his subsequent work which enabled him to find “a hierarchical structure of intellect, with “g” at the top, and the “primary abilities” (whose inter correlations necessitated the postulation of “g”) at a lower level; the actual tests used, whose inter correlations gave rise to the “primary abilities”, would if course be at a lower level still” (Eysenck, 1972, p.2).

Self Assessment Questions

1) How did Spearman develop his two-factor theory?

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2) How an intercorrelation matrix is used for identifying the factors?

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3) What are the two main contributions of Spearman according to Nunnally?

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4) Present a critical appraisal of two-factor theory?.

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1.4 DAS, NAGLIERY AND KIRBY’S PASS THEORY

The theories of Spearman, Thorndike, Thomson, Thurstone that we discussed above, and other similar ones, are based on isolating factors after administering several intelligence tests over a large sample of subjects. They did not take into account how an input, e.g. a test item is received and processed and how a cognitive reorganisation takes place prior to giving a response. Das, Nagliery, and Kirby (1994) have developed a theory-based, multidimensional view of intelligence with constructs borrowed from contemporary research in neuropsychology, information processing and human cognition.

This theory has four components: Planning, Attention-Arousal, Simultaneous, and Successive (PASS) processing systems (see Fig.1.3).

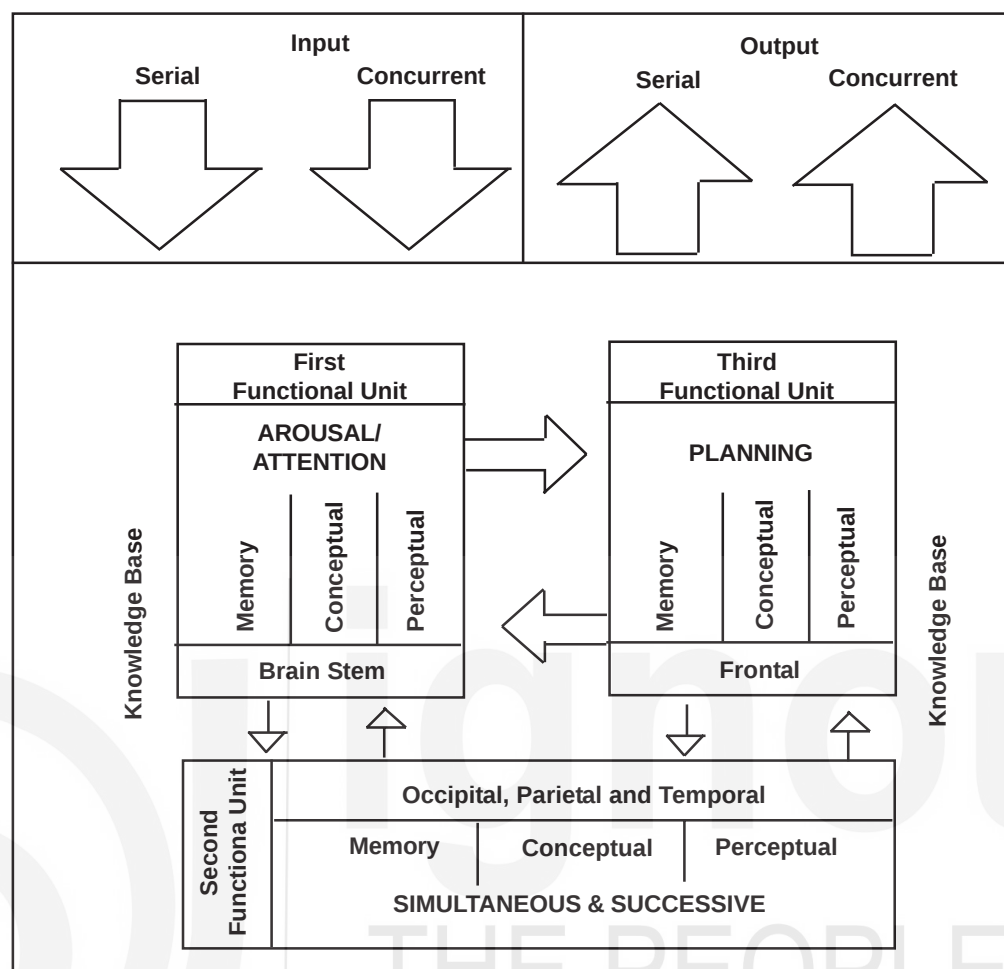


Fig. 1.3: Pictorial presentation of PASS model

(Source: Das, 2004; p.10)

Alexander R. Luria's (1966; 1973; 1980) pioneering researches in the fields of neuropsychology, information processing, and cognitive psychology have provided the theoretical foundation to the PASS theory. Luria divided human cognitive processes into three primary functional units.

- i) Maintaining appropriate cortical arousal and attention to allow for adequate vigilance and discrimination between stimuli is the primary function of the first unit.
- ii) The second unit is responsible for obtaining, elaborating upon, and storing information using successive and simultaneous processes.
- iii) The third functional unit is responsible for programming as well as the regulation and control of mental activity (i.e., executive functioning). Planning, self-monitoring, and structuring of cognitive activities are provided by this functional unit.

To elaborate further, the first functional unit, attention-arousal, is located in the brain stem and reticular activating system. This unit provides the brain with the appropriate level of arousal or cortical tone and "directive and selective attention" (Luria, 1973, p. 273).

Attentional processes are engaged when a multidimensional stimulus array is presented to the subject, and the task requires selective attention to one dimension,

and the inhibition of response to other, often more salient stimuli. Luria stated that only under optimal conditions of arousal can the more complex forms of attention involving “selective recognition of a particular stimulus and inhibition of responses to irrelevant stimuli” occur (Luria, 1973, p.271). Moreover, Luria also maintains that only when sufficiently aroused and when attention is adequately focused can an individual utilise processes within the second and third functional units.

About the second functional unit, Luria described “two basic forms of integrative activity of the cerebral cortex” which are responsible for “receiving, analysing, and storing information” through the use of simultaneous and successive processing.

Simultaneous processing is associated with the occipital-parietal areas of the brain.

The essential aspect of simultaneous processing is the surveyability; that is, each element is related to every other element. Das (2004) has explained with the help of following example.

“To produce a diagram correctly when given the instruction, “draw a triangle above a square that is to the left of a circle under a cross,” the relationships among the shapes must be correctly comprehended” (Das, 2004, p. 9).

Successive processing is associated with the fronto-temporal areas of the brain and involves the integration of stimuli into a specific serial order where each component is related to the next. That is, in successive synthesis, “each link integrated into a series can evoke only a particular chain of successive links following each other in serial order”. For example, in language processing, successive processes involved with are decoding and producing syntax, and articulating speech.

The third functional unit is located in the prefrontal divisions of the frontal lobes of the brain (Luria, 1980). Luria stated that “the frontal lobes synthesize the information about the outside worlds . . . and are the means whereby the behaviour of the organism is regulated in conformity with the effect produced by its actions” (p.263).

Planning processes provide for the programming, regulation and verification of behaviour and are responsible for behaviours, such as asking questions, problem solving, and the capacity for self-monitoring. Other activities of the third functional unit include regulation of voluntary activity, impulse control, and various linguistic skills, such as spontaneous conversation. The third functional unit provides for the most complex aspects of human behaviour including personality and consciousness.

All four processes of the PASS theory have been operationally defined by Das, Nagliery and Kirby (1994). Planning processes are required when a test demands that the individual makes some decisions about how to solve a problem, execute an approach, activate attentional, simultaneous, and successive processes, monitor the effectiveness of the approach and modify it as needed.

Planning processes are involved when a person is asked to decide how to perform a test and is inhibited by the imposition of strict rules about how to perform. For

example, writing a composition involves generation of a plan, organisation of the ideas, control over what is presented when, examination of the product, and revisions to make the final result consistent with the intended goal.

Planning is clearly associated with the frontal lobes, especially the prefrontal cortex. It has connections with the rest of the brain as described before, including the parietal, temporal, and occipital lobes that are responsible for information coding (simultaneous and successive processing), as well as with sub cortical areas that determine the level of arousal and affective reactions to different conditions on the basis of past experiences.

Attention arousal is a complex process of the PASS theory. Arousal keeps the persons alert. It is associated with the activity of the brain stem and the lower part of the cerebral cortex. Attention on the other hand is associated with the frontal lobes and the lower portion of the cortex together.

Simultaneous processing is broadly associated with the occipital and the parietal lobes, while successive processing is associated with frontal temporal lobes

Knowledge base is an integral component of the PASS model and therefore all processes are embedded within this dimension. The base of knowledge included in the PASS model is intended to represent all information obtained from the cultural and social background of the individual, because this determines the form of mental activity. Children's use of language to analyse, generalise, and encode experience is a critical determinant of the base of knowledge, because mental processes cannot develop apart from the appropriate forms of social life.

The final component of the PASS model is output or action and behaviour. It is suggested that both simultaneous and successive processes must be used in the processing of cognitive tasks. Das (1998, p. 221) has thus explained its salient features: "The PASS theory of intelligence (1) has given us tests to measure intelligence as a set of cognitive processes, (2) discusses what the major processes are, and (3) guides us in the remediation of processing difficulties."

Cognition is a dynamic process that works within the context of the individual's knowledge base, responds to his experiences, and is subject to developmental variations. When considering the measurement of cognitive processes, it must be noted that the effective processing is accomplished through the integration of knowledge with planning, attention, simultaneous, and successive processes as demanded by the particular task. Although these processes are interrelated and nonstop, they are not equally involved in all tasks. For that reason, cognitive assessment tasks for planning, attention, simultaneous, and successive processing were developed to adhere to PASS theory and predominantly require a specific cognitive process (Das, Nagliery, & Kirby, 1994).

Taking the lead of Das and by using the multivariate techniques of cluster analysis, Ronning (2004) developed ability/achievement normative taxonomies for reading and mathematics of children in the age group of 8 to 17 years. The core profiles that emerged provided important comparisons for evaluating individual profiles, as well as added to the information explaining common variability in the child population. The taxonomies were based upon 711 children in the 8 to 17 year old portion of the standardisation sample of the Cognitive Assessment System (CAS) who were co-administered the Woodcock-Johnson Tests of Achievement-Revised

(WJ-R ACH). Ability/reading and ability/mathematics normative taxonomies were developed from the Planning, Attention, Simultaneous, and Successive scales of the Cognitive Assessment System (Das, Nagliery, & Kirby, 1994) in conjunction with four reading and three math WJ-RACH subscales. Eight reading and five math clusters were identified and described using demographics and overall ability and achievement levels, which enabled Ronning (2004) to develop intervention programme also.

1.4.1 Critical Appraisal of PASS Theory

The PASS theory has provided a novel approach to assess intelligence. It is cognitive in orientation and it bases its tests on neuropsychological theories of Luria. Of great importance of Das, Nagliery, and Kirby (1994) was to move away from conventional tests of intelligence and to provide a theory-based multidimensional view of intelligence that is built on contemporary research on human cognition. It has a practical utility also. Undoubtedly all tests of intelligence attempt at tapping cognitive aspects. However, most of them approximate to the underlying processing of informational input.

Another attribute of this theory is that it has developed a Cognitive Assessment System (CAS) test also, which offers a unique opportunity to examine the relative contribution of cognitive processes as a testee undergoes a testing scenario. CAS has four subscales, named after PASS, and the test items are specially designed to assess a testee's proficiency in each of them separately as well as collectively.

Self Assessment Questions

- 1) How are neuropsychological concepts of Luria incorporated in the PASS theory?

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- 2) Why planning has been given so much importance in PASS theory?

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- 3) What is the main contribution of knowledge base in PASS theory?

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4) Present a critical appraisal of PASS theory.

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1.5 LET US SUM UP

Intelligence is a concept that is so commonly referred by each one of us, but which is so difficult to define. There is a general agreement that thinking, reasoning, problem solving and decision making are all of relevance to intelligence. However, there is less agreement about the extent to which each component contributes to it. Much research on intelligence during the first half of the twentieth century was based upon the factor-analytic approach. This approach was pioneered by Spearman (1904;1923;1927) and his two-factor theory achieved the desired success in stimulating a whole host of researches in identifying the factors of intelligence. Eventually Spearman's work culminated in describing the hierarchical structure of intelligence. The research work that was directed at testing his theory extended the evidence that is consistent with the view that there is a general factor of intelligence (the "g"), together with a number of more specific factors. The various measures of intelligence, about which we shall study in a subsequent unit, have attested the ubiquitous presence of "g" as well.

It is a known fact that tests of intelligence, beginning with that of Binet and Simon (1905), have played an important input in predicting school success (or its absence) since the turn of the century. The various tests that were developed in criticism of Spearman, however, incorporated a number of similar characteristics. Intelligence test batteries differ in other ways, such as the theoretical underpinnings and appropriate uses of the test, as well as the types of questions utilised. We have already discussed the views of Thurstone who extended support to Spearman when methodology was followed as suggested by Spearman. Jensen (1998) and Carroll (1993) have found the presence of "g" in their factor analyses.

The PASS theory of Das, Nagliery and Kirby (1994) is an information processing theory, which has taken its inspiration from the pioneering neuropsychological and cognitive psychological researches of Alexander Luria (1966; 1973; 1980). Luria described human cognitive processes within the framework of three functional units. The function of the first unit is cortical arousal and attention; the second unit codes information using simultaneous and successive processes; and the third unit provides for planning, self-monitoring, and structuring of cognitive activities. Luria's work on the functional aspects of brain structures formed the basis of the PASS model and was used as a blueprint for defining the important components of human intellectual competence.

A Cognitive Assessment System (CAS) has also been developed by Das, Nagliery and Kirby (1994) and a number of researches on various aspects of human cognition have extended increasing support to the contentions of the proponents of this theory. The Cognitive Assessment System is an individualised assessment that may be used for a variety of purposes, including diagnosis, eligibility, determination of discrepancies, reevaluation, and instructional planning.

1.6 UNIT END QUESTIONS

- 1) How do general people explain intelligence?
- 2) What commonalities has Sternberg noted in the 1921 and 1986 surveys about definitions of intelligence?
- 3) Give a historical account of individual differences.
- 4) How far it is correct to state that Spearman was concerned much more with understanding intelligence than measuring it?
- 5) Discuss the salient features of two-factor theory.
- 6) Critically appraise Spearman's two-factor theory.
- 7) What constructs has PASS theory borrowed from the fields of neuropsychology and information processing?
- 8) Give operational definitions of all four processes of PASS theory.

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UNIT 2 MULTIPLE THEORIES OF INTELLIGENCE (GUILFORD, GARDNER AND STERNBERG)

Structure

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2.0 INTRODUCTION

In Unit 1 we discussed a number of definitions of intelligence. We also noted that there is some sort of an agreement that reasoning, problem solving, thinking and other cognitive processes are all of relevance to intelligence. In other words it can be stated that intelligence comprises a variety of human cognitive activities such as learning from past experiences, adaptation to new situations, and thinking abstractly. In the first decade of the twentieth century, factor-analytic approach became popular and the debate about whether or not intelligence is a unitary construct still continues. Nowadays intelligence is conceived in terms of multiple abilities. In the present unit we will discuss three important theories of intelligence. First, we will explain the salient features of Guilford's Structure-of-Intellect

Theory, then we will turn our attention to highlight Howard Gardner's Theory of Multiple Intelligence, and finally we will discuss Sternberg's Triarchic Theory of intelligence.

2.1 OBJECTIVES

After reading this unit, you will be able to:

- Describe the contemporary approaches to intelligence;
- Elucidate Guilford's Structure-of-Intellect theory;
- Explain the multiple intelligences identified by Gardner;
- Differentiate between Guilford's structure-of-intellect theory and Gardner's theory of multiple intelligences;
- Define the triarchic theory of intelligence propounded by Sternberg; and
- Differentiate between Gardner's theory of multiple intelligences and Sternberg's triarchic theory of intelligence.

2.2 GUILFORD'S STRUCTURE-OF-INTELLECT THEORY

There are two distinct approaches to understand the nature of intelligence. The proponents of the first approach viewed intelligence as a single entity and developed their theories that take into account the biological reasons for intelligence. They view neural processing speed as the root of intelligence as such their theory has an effective causal explanation. The proponents of the second notion believed that intelligence is not a single or unitary ability, rather there are several intelligences. As for multiple intelligences, there are many theorists in that school of thought as well. Some of the theories presented by the proponents of multiple intelligences are excessive and have too many constructs to account for the explanation of intelligence. Guilford's Structure-of-Intellect (SOI) Model is such a multiple intelligences theory.

J. P. Guilford, was born on March 7, 1897 in Marquette, Nebraska. His interest in individual differences started from his childhood, when he observed the differences in ability among the members of his own family. As an undergraduate student at the University of Nebraska, he worked as an assistant in the psychology department. At Cornell University from 1919 to 1921, he studied under Edward Titchener and conducted intelligence testing on children. During his time at Cornell University, he also served as director of the university's psychological clinic. From 1927 to 1928, Guilford worked at the University of Kansas, after which he became Associate Professor at University of Nebraska, remaining there from 1928 to 1940. In 1940 he was appointed as psychology professor at the University of Southern California, where he stayed until 1967. Guilford retired from teaching in 1967, but continued to write and publish. He died on November 26, 1987.

Guilford believed that intelligence was not a monolithic, global attribute but a combination of multiple abilities, which were relatively independent. He applied factor analytic method to study these mental abilities. Building upon the views of Thurstone (1939), Guilford rejected Charles Spearman's view that intelligence

could be characterised by a single numerical parameter (“general intelligence factor” or *g*). He also rejected broad factor groups like that of Thurstone’s primary abilities. According to him, intelligence consists of numerous intellectual abilities. By the 1950’s, Guilford felt there needed to be a system developed to classify the new mental abilities being discovered.

In 1956, the first version of the Structure-of-Intellect (SOI) model was presented. The structure of intellect defines intelligence as a systematic collection of abilities or functions for processing different kinds of items of information in various ways. Originally the SOI model included four types of mental contents dimension (figural, symbolic, semantic, and behavioural), five types of operations dimension (cognition, memory, evaluation, convergent production and divergent production), and six types of products dimension (units, classes, relations, systems, transformations, and implications), thus resulting in 120 factors, with over 100 having been empirically verified. This model is represented as a cube with each of the three dimensions occupying one side. Many of the abilities are believed to be correlated with each other. The model also suggests where new abilities may be discovered based on existing abilities.

Subsequently, Guilford (1977) modified his model and divided *figural* factor of the content dimension into *visual* and *auditory* factors, thus making five types of the contents dimension, instead of the original four types. In the modified version the number of cells became 150 (5 contents $\times$ 5 Operations $\times$ 6 Products= 150 cells). The definition given by Guilford for each of these is too lengthy to present here; they will be described very briefly.

2.2.1 The Contents Dimension

This dimension includes the broad areas of information in which operations are applied. It has been divided into four categories.

- *Visual* - Information arising from stimulation on the retina in the form of an image.
- *Auditory* – Information arising from stimulation of the cochlea of the ear as image.
- *Symbolic* - Information perceived as symbols or signs that have no meaning by themselves; for example, Arabic numerals or the letters of an alphabet.
- *Semantic* - Information perceived in words or sentences, whether oral, written, or silently in one’s mind.
- *Behavioural* – Information perceived as acts of an individual/ individuals.

2.2.2 The Operations Dimension

This consists of five kinds of operation or general intellectual processes:

- *Cognition* - The ability to understand, comprehend, discover, and become aware.
- *Memory* - The ability to memorise information.
- *Divergent Production* - The process of generating multiple solutions to a problem
- *Convergent Production* - The process of deducing a single solution to a problem.
- *Evaluation* - The process of judging whether an answer is accurate, consistent, or valid.

2.2.3 The Products Dimension

As the name suggests, this dimension contains results of applying particular operations to specific contents. There are six kinds of products, they are:

- *Unit* - Represents a single item of information.
- *Class* - A set of items that share some attributes.
- *Relation* - Represents a connection between items or variables; may be linked as opposites or in associations, sequences, or analogies.
- *System* - An organisation of items or networks with interacting parts.
- *Transformation* - Changes perspectives, conversions, or mutations to knowledge; such as reversing the order of letters in a word.
- *Implication* - Predictions, inferences, consequences, or anticipations of knowledge.

Some examples may provide a feel for the kinds of distinctions made in this model. Suppose a subject is given a long list of unrelated words to study and is asked to recall them later. The *content* of this scale is “semantic,” since it involves words; the *operation* is “memory”; and the *product* is the recall of words as “units.”

2.2.4 Evaluation

Guilford’s Structure-of-Intellect theory is more complex than Thurstone’s, which grew out of a massive analysis of a great many existing tests. Research from different fields, such as developmental psychology, artificial intelligence, and neurology, shows that the mind consists of several independent (albeit interdependent) modules or “intelligences.” According to Eysenck (1972), Guilford “concentrated most of his studies on populations with a restricted range of intelligence, thus reducing the scope of “g”; and he has used orthogonal methods of rotation, thus ignoring the correlations between “simple structure” factors which would have emerged if he had used an oblique method of rotation...Of more practical importance is the criticism that Guilford’s factors are so narrow and specialised that they have little value in prediction, as in educational and vocational guidance” (p. 3). In spite of these criticisms it is important to note that Guilford left a significant mark on research into intelligence. Many tests that are still used in modern intelligence testing were modified and developed under his guidance.

Self Assessment Questions

- 1) What do you understand by the term multiple intelligences?

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2) Elucidate Structure of Intellect Theory.

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3) What are the three dimensions of Guilford's theory of MI?

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4) Critically evaluate the construct-of-intellect theory of Guilford.

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2.3 GARDNER'S THEORY OF MULTIPLE INTELLIGENCES

Howard Gardner was born in Scranton, Pennsylvania in 1943. In order to make a career in law, he joined Harvard University. However, he was lucky enough to have Eric Erikson as a tutor. In Howard Gardner's words Erikson probably 'sealed' his ambition to be a scholar (1989). He entered Harvard's doctoral programme in 1966, and in the following year became part of the Project Zero research team on arts. Howard Gardner completed his PhD in 1971 (his dissertation was on style sensitivity in children). He remained at Harvard. Alongside his work with Project Zero, he was a lecturer (1971-1986) and then professor in education (1986-). His first major book, *The Shattered Mind* appeared in 1975 and some fifteen have followed.

Project Zero provided an environment in which Howard Gardner could begin to explore his interest in human cognition. He proceeded in a very different direction to the dominant discourses associated with Piaget and with psychometric testing. Project Zero developed as a major research centre for education and provided an intellectual home for a significant grouping of researchers. A key moment came with the establishment of the Project on Human Potential in the late 1970s (funded by Bernard van Leer Foundation) to 'assess the state of scientific knowledge concerning human potential and its realisation'.

In 1981 Gardner was awarded a MacArthur Prize Fellowship in support of Project Zero at Harvard University. An announcement of the award quoted Gardner as saying early in his career, that he had been a committed Piagetian, but as he pursued his own studies he came to view Piaget's theories as "too narrow a notion of how the human mind works." He noted further that he did not believe there was "one form of cognition which cuts across all human thinking. There are multiple intelligences with autonomous intelligence capacities." This statement heralded the writing of his book *Frames of Mind*, which was published in 1983.

Gardner (1983) claimed that most previous conceptualisations of intelligence had been too narrowly based. He argued that evidence from several different sources (e.g. cross-cultural accounts of cognition, studies of exceptional groups, psychometric data, and psychological training studies) pointed to the existence of several intelligences.

According to Gardner (1999), intelligence is much more than IQ because a high IQ in the absence of productivity does not equate to intelligence. In terms of his definition (1983): "Intelligence is a bio-psychological potential to process information that can be activated in a cultural setting to solve problems or create products that are of value in a culture". Consequently, instead of intelligence being a single entity described psychometrically with an IQ score, Gardner's definition views it as many things. He endeavored to define intelligence in a much broader way than did the psychometricians. To achieve this goal Gardner (1983; 1999) established several criteria for defining intelligence. In identifying capabilities to be considered for one of the "multiple intelligences" the construct under consideration had to meet eight criteria rather than resting on the results of a narrow psychometric approach.

To qualify as "intelligence" the particular capacity under study was considered from multiple perspectives consisting of eight specific criteria drawn from the biological sciences, logical analysis, developmental psychology, experimental psychology, and psychometrics. The criteria to consider "candidate intelligences" (Gardner, 1999) are:

- the potential for brain isolation by brain damage,
- its place in evolutionary history,
- the presence of core operations,
- susceptibility to encoding,
- a distinct developmental progression,
- the existence of idiot-savants, prodigies and other exceptional people,
- support from experimental psychology, and
- support from psychometric findings.

From the above eight criteria, Gardner initially formulated a list of seven intelligences. In 1999, he added naturalist intelligence as the eighth. He has also considered inclusion of existential intelligence as the ninth intelligence in his theory (Slavin, 2009). The first two have been typically valued in schools; the next three are usually associated with the arts; the next two are what Gardner called 'personal intelligences'; while the newly added final two are related to aesthetics and philosophical views of life (Gardner 1999). Each of these intelligences will now be briefly described.

2.3.1 Linguistic Intelligence

This intelligence includes the ability to effectively use language to express oneself rhetorically or poetically; and as a means to remember information. Writers, poets, lawyers and speakers are among those that Howard Gardner sees as having high linguistic intelligence. This area has to do with words, spoken or written. People with high verbal-linguistic intelligence display a facility with words and languages. They are typically good at reading, writing, telling stories and memorizing words along with dates. They tend to learn best by reading, taking notes, listening to lectures, and discussion and debate. Those with verbal-linguistic intelligence learn foreign languages very easily as they have high verbal memory and recall, and an ability to understand and manipulate syntax and structure. Careers that suit those with this intelligence include writers, lawyers, policemen, philosophers, journalists, politicians, poets, and teachers.

2.3.2 Logical-mathematical Intelligence

This intelligence consists of the capacity to analyse problems logically, carry out mathematical operations, and investigate issues scientifically. In Howard Gardner's words, it entails the ability to detect patterns, reason deductively and think logically. This intelligence is most often associated with scientific and mathematical thinking. This area has to do with logic, abstractions, reasoning, and numbers. While it is often assumed that those with this intelligence naturally excel in mathematics, chess, computer programming and other logical or numerical activities, a more accurate definition places less emphasis on traditional mathematical ability and more on reasoning capabilities, abstract patterns of recognition, scientific thinking and investigation, and the ability to perform complex calculations. It correlates strongly with traditional concepts of "intelligence" or IQ. Careers which suit those with this intelligence include scientists, physicists, mathematicians, logicians, engineers, doctors, economists and philosophers.

2.3.3 Musical Intelligence

This intelligence involves skill in the performance, composition, and appreciation of musical patterns. It encompasses the capacity to recognise and compose musical pitches, tones, and rhythms. According to Howard Gardner musical intelligence runs in an almost structural parallel to linguistic intelligence. This area has to do with sensitivity to sounds, rhythms, tones and music. People with a high musical intelligence normally have good pitch and may even have absolute pitch and are able to sing, play musical instruments, and compose music. Since there is a strong auditory component to this intelligence, those who are strongest in it may learn best via lecture. Language skills are typically highly developed in those whose base intelligence is musical. In addition, they will sometimes use songs or rhythms to learn. They have sensitivity to rhythm, pitch, meter, tone, melody or timbre. Careers that suit those with this intelligence include instrumentalists, singers, conductors, disc-jockeys, orators, writers and composers.

2.3.4 Bodily-kinesthetic Intelligence

It entails the potential of using one's whole body or parts of the body to solve problems. It is the ability to use mental abilities to coordinate bodily movements. In theory, people who have bodily-kinesthetic intelligence should learn better by involving muscular movement (e.g. getting up and moving around into the

learning experience), and are generally good at physical activities such as sports or dance. They may enjoy acting or performing, and in general they are good at building and making things. They often learn best by doing something physically, rather than by reading or hearing about it. Careers that suit those with this intelligence include: athletes, dancers, musicians, actors, surgeons, doctors, builders, police officers, and soldiers. Although these careers can be duplicated through virtual simulation, they will not produce the actual physical learning that is needed in this intelligence.

2.3.5 Spatial Intelligence

Spatial intelligence involves the potential for recognising and manipulating the patterns of both wide spaces such as those negotiated by pilots or navigators, and confined spaces such as those encountered by sculptors, architects or championship chess players. This area deals with spatial judgment and the ability to visualise with the mind's eye. Careers which suit those with this type of intelligence include artists, designers and architects. A spatial person is also good with puzzles.

2.3.6 Interpersonal Intelligence

This intelligence is concerned with the capacity to understand the intentions, motivations and desires of other people. It allows people to work effectively with others. Educators, sales people, religious and political leaders and counselors all need a well-developed interpersonal intelligence. This area has to do with interaction with others. In theory, people who have a high interpersonal intelligence tend to be extrovert, characterised by their sensitivity to others' moods, feelings, temperaments and motivations, and their ability to cooperate in order to work as part of a group. They communicate effectively and empathise easily with others, and may be either leaders or followers. They typically learn best by working with others and often enjoy discussion and debate. Careers that suit those with this intelligence include sales, politicians, managers, teachers, and social workers.

2.3.7 Intrapersonal Intelligence

This entails the capacity to understand oneself, to appreciate one's feelings, fears and motivations. In Howard Gardner's view it involves having an effective working model of ourselves, and to be able to use such information to regulate our lives. This area has to do with introspective and self-reflective capacities. People with intrapersonal intelligence are intuitive and typically introverted. They are skillful at deciphering their own feelings and motivations. This refers to having a deep understanding of the self; what are your strengths/ weaknesses, what makes you unique, you can predict your own reactions/ emotions. Careers which suit those with this intelligence include philosophers, psychologists, theologians, lawyers, and writers. People with intrapersonal intelligence also prefer to work alone.

2.3.8 Naturalistic Intelligence

This intelligence has to do with nature, nurturing and relating information to one's natural surroundings. Such a person demonstrates expertise in recognition and classification of the numerous species - the flora and fauna – of her or his environment. Careers which suit those with this intelligence include naturalists, farmers and gardeners.

2.3.9 Existential Intelligence

This is an ability to contemplate phenomena or questions beyond sensory data, such as the infinite and infinitesimal. Career which suits those with this intelligence include cosmologists, and philosophers.

According to Gardner (1983), each of these “intelligences” has a specific set of abilities that can be observed and measured. The first two forms of intelligence are typically the abilities that contribute to strong performance in traditional school environments and to producing high scores on most IQ measures or tests of achievement. The next three forms are very crucial for artists. The next two, viz., interpersonal and intrapersonal intelligences, are personal intelligences. Interpersonal intelligence indicates a person’s ability to recognise the intentions, feelings and motivations of others. People who possess and develop this quality are likely to work well with others and may choose fields like sales, teaching, counselling or politics in order to use them when required. Intrapersonal intelligence is described as the ability to understand oneself and use that information to regulate one’s own life. The last two intelligences are related to aesthetic feelings and philosophical issues. Gardner (1998) nominated three additional candidate intelligences: Naturalist, Spiritual and Existential intelligence and evaluated them in the context of the eight criteria he had established in his research and outlined earlier in this unit.

In *Frames of Mind*, Howard Gardner (1983) treated the personal intelligences ‘as a piece’. Because of their close association in most cultures, they are often linked together. However, he still argues that it makes sense to think of two forms of personal intelligence. Gardner claimed that the seven intelligences rarely operate independently. They are used at the same time and tend to complement each other as people develop skills or solve problems.

According to Gardner, our schools as well as the society focus most of its attention on linguistic and logical-mathematical intelligence. Gardner emphasises that we should also place equal attention on individuals who show gifts in the other intelligences: the artists, architects, musicians, naturalists, designers, dancers, therapists, entrepreneurs, and others who enrich the world in which we live. Unfortunately, many children who have these gifts don’t receive much reinforcement for them in their schools. Many of these kids, in fact, end up being labeled “learning disabled,” attention deficit disorder” (ADD), or simply underachievers, when their unique ways of thinking and learning aren’t addressed by a heavily linguistic or logical-mathematical classroom.

The theory of multiple intelligences proposes a major transformation in the way our schools are run. It suggests that teachers need to be trained to present their lessons in a wide variety of ways using music, cooperative learning, art activities, role play, multimedia, field trips, inner reflection, and much more. The theory of multiple intelligences also has strong implications for adult learning and development. Many adults find themselves in jobs that do not make optimal use of their most highly developed intelligences (for example, the highly bodily-kinesthetic individual who is stuck in a linguistic or logical desk-job when he or she would be much happier in a job where they could move around, such as a recreational leader, a forest ranger, or physical therapist).

The theory of multiple intelligences gives adults a whole new way to look at their lives, examining potentials that they left behind in their childhood (such as

a love for art or drama) but now have the opportunity to develop through courses, hobbies, or other programmes of self-development.

2.3.10 Evaluation

Howard Gardner's work around multiple intelligences has had a profound impact on thinking and practice in education. His theory has wide implications in the field of teaching and learning. For example, if you're teaching or learning about the law of supply and demand in economics, you might read about it (linguistic), study mathematical formulas that express it (logical-mathematical), examine a graphic chart that illustrates the principle (spatial) and then utilise all information into your teaching programme. One of the interesting characteristics of Gardner's theoretical approach is that several of the intelligences are not specifically cognitive in nature.

The concept of multiple intelligences can be quite useful in investigating specialised functions or clinical cases of mental dysfunctions. The major objection to the concept, however, is that an excessive importance is placed on the independence of these intelligences from one another and divides human beings on the basis of a new typology. In fact, the brain and indeed the human being act as a whole, and no one mental activity can be truly independent of another.

Gardner's theory has also been criticized by many psychologists on several grounds. The fundamental criticism of this theory is the belief by scholars that each of the seven multiple intelligences is in fact a cognitive style rather than a stand-alone construct (Morgan, 1996). Hunt (2001) criticised Gardner's theory on the ground that "theory of multiple intelligences cannot even be evaluated by the canons of science until it is made specific enough to generate measurement models" (p. 7). M. W. Eysenck (1990) remarked that "there are grounds for doubting that he has identified different intelligences rather than different abilities" (p. 193). As Sternberg and Frensch (1990) pointed out, it seems strange to describe someone who is tone deaf or physically uncoordinated as unintelligent. Other criticisms include the notion that the theory of multiple intelligences is not empirical, is incompatible with "g", heritability, and environmental influences, and broadens the construct of intelligence so widely as to render it meaningless.

However, we can conclude following the contentions of Das (1999), that "it can certainly be stated that the different types of intelligence included in Gardener's system of multiple intelligences is consistent with investigations of distinct talents and skills in individuals. We do study the nature of musical ability, strategies involved in playing chess, the thought processes of logicians and mathematicians, and early indicators of bring a cricket player, or a smooth, persuasive sales person" (p.222).

Self Assessment Questions

1) Describe Project Zero.

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2) What are the multiple intelligences identified by Gardner?

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3) Evaluate the importance of Gardner's approach in the explanation of intelligence.

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4) How is Gardner's theory differ from Guilford's construction of intellect theory?

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5) What is existential intelligence? Describe

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2.4 STERNBERG'S TRIARCHIC THEORY OF INTELLIGENCE

Robert Jeffrey Sternberg (born December 8, 1949), is an American psychologist and psychometrician. He received his B.A. degree from the Yale University and Ph.D. from the Stanford University under the supervision of Gordon Bower. He was Provost at Oklahoma State University. He was formerly the Dean of Arts and Sciences at Tufts University, IBM Professor of Psychology and Education at Yale University and the President of American Psychological Association. He holds ten honorary doctorates from one North American, one South American, and eight European universities, and additionally holds an honorary professorate at the University of Heidelberg in Germany. He is also a Distinguished Associate of The Psychometrics Centre at the University of Cambridge.

The triarchic theory of intelligence developed by Sternberg is “a comprehensive theory, because it takes into account social and contextual factors apart from human abilities” (Li, 1996). Sternberg (1985) felt that the theories that preceded him were not incorrect, but rather, incomplete. Consequently, his theory, like Gardner’s, takes into account creative or musical intelligence. But as for the other six intelligences from Gardner’s theory, Sternberg classified them into two different types of intelligences: analytic (or academic) and practical. These two types of intelligence differ and are defined as follows: Analytic problems tend to have been formulated by other people, be clearly defined, come with all information needed to solve them, have only a single right answer, which can be reached by only a single method, be disembodied from ordinary experience, and have little or no intrinsic interest. Practical problems tend to require problem recognition and formulation, be poorly defined, require information seeking, have various acceptable solutions, be embedded in and require prior everyday experience, and require motivation and personal involvement. (Neisser, *et al.*, 1996). If an individual could solve one or the other of these types of problems well, then that individual would have a high analytic or practical intelligence, respectively. Also, there exists virtuosos, or individuals who are extremely talented in the fine arts, these people would have a high creative intelligence.

Sternberg’s triarchic theory includes three facets or subtheories: (i) the componential subtheory which outlines the structures and mechanisms that underlie intelligent behaviour categorised as metacognitive, performance, or knowledge acquisition components, (ii) the experiential subtheory that proposes intelligent behaviour be interpreted along a continuum of experience from novel to highly familiar tasks/situations, (iii) the contextual subtheory which specifies that intelligent behaviour be defined by the socio-cultural context in which it takes place and involves adaptation to the environment, selection of better environments, and shaping of the present environment. According to Sternberg, a complete explanation of intelligence entails the interaction of these three subtheories. The componential subtheory specifies the potential set of mental processes that underlies behaviour (i.e., how the behaviour is generated) while the contextual subtheory relates intelligence to the external world in terms of what behaviours are intelligent and where. The experiential subtheory addresses the relationship between the behaviour in a given task/situation and the amount of experience of the individual in that task/situation.

Triarchic Theory

Componential Subtheory	Experiential Subtheory	Contextual Subtheory
Metacomponents	Novelty	Adaptation
Performance	Automation	Selection
Acquisition		Shaping
Acquisition		Shaping

2.4.1 Componential or Analytical Facet or Subtheory

Componential or analytical intelligence is the ability to complete academic, problem-solving tasks. These types of tasks usually present well-defined problems that have only a single correct answer. It is similar to the standard psychometric definition of intelligence e.g. as measured by academic problem solving, analogies

and puzzles, and corresponds to his earlier componential intelligence. Sternberg considers that this reflects how an individual relates to his internal world. According to Sternberg, analytical intelligence (academic problem-solving skills) is based on the joint operations of metacomponents and performance components and knowledge acquisition components of intelligence.

Metacomponents control, monitor and evaluate cognitive processing. These are the *executive* functions to order and organise performance and knowledge acquisition components. They are the higher-order processes that order and organise the performance components. They are used to analyse problems and pick a strategy for solving them. They decide what to do and the performance components actually do it.

Performance Components execute strategies assembled by the metacomponents. They are the basic operations involved in any cognitive act. They are the cognitive processes that enable us to encode stimuli, hold information in short-term memory, make calculations, perform mental calculations, mentally compare different stimuli, and retrieve information from long-term memory.

Knowledge acquisition components are the processes used in gaining and storing new knowledge – i.e. capacity for learning. The strategies you use to help memorize things exemplify the processes that fall into this category.

2.4.2 Experiential or Creative Facet or Subtheory

Experiential or creative intelligence is the ability to successfully deal with new and unusual situations by drawing on existing knowledge and skill. Individuals high in creative intelligence may give ‘wrong’ answers because they see things from a different perspective. Thus creative intelligence involves insights, synthesis and the ability to react to novel situations and stimuli. Sternberg considers it as experiential aspect of intelligence because it reflects how an individual connects the internal world to external reality. Sternberg considers the creative facet to comprise the ability that allows people to think creatively and that which allows people to adjust creatively and effectively to new situations. Sternberg believes that more intelligent individuals will also move from consciously learning in a novel situation to automating the new learning so that they can attend to other tasks. Thus experiential facet deals mainly with how well a task is performed with regard to how familiar it is.

Sternberg splits the role of experience into two parts: novelty and automation. A *novel* situation is one that you have never experienced before. People who are adept at managing a novel situation can take the task and find new ways of solving it that the majority of people would not notice (Sternberg, 1997). A process that has been *automated* has been performed multiple times and can now be done with little or no extra thought. Once a process is automatised, it can be run in parallel with the same or other processes. The problem with novelty and automation is that being skilled in one component does not ensure that you are skilled in the other also (Sternberg, 1997).

2.4.3 Contextual or Practical Facet or Subtheory

Sternberg’s third subtheory of intelligence, called practical or contextual, “deals with the mental activity involved in attaining fit to context” (Sternberg, 1985). It is the ability to adapt to everyday life by drawing on existing knowledge and

skills. Practical intelligence enables an individual to understand what needs to be done in a specific setting and then do it. Through the three processes of adaptation, shaping, and selection, individuals create an ideal fit between themselves and their environment. This type of intelligence is often referred to as “street smarts.”

Adaptation occurs when one makes a change within oneself in order to better adjust to one’s surroundings (Sternberg, 1985). For example, when the weather changes and temperatures drop, people adapt by wearing extra layers of clothing to remain warm. *Shaping* occurs when one changes their environment to better suit one’s needs (Sternberg, 1985). A teacher may invoke the new rule of raising hands to speak to ensure that the lesson is taught with least possible disruption. The process of *selection* is undertaken when a completely new alternate environment is found to replace the previous, unsatisfying environment to meet the individual’s goals (Sternberg, 1985). For instance, immigrants leave their lives in their homeland countries where they endure economical and social hardships and go to other countries in search of a better and less strained life.

Sternberg’s *triarchic theory of intelligence* contends that intelligent behaviour arises from a balance between analytical, creative and practical abilities, and that these abilities function collectively to allow individuals to achieve success within particular socio-cultural contexts (Sternberg, 1988; 1997; 1999). Analytical abilities enable the individual to evaluate, analyse, compare and contrast information. Creative abilities generate invention, discovery, and other creative endeavors. Practical abilities tie everything together by allowing individuals to apply what they have learned in the appropriate setting. To be successful in life the individual must make the best use of his or her analytical, creative and practical strengths, while at the same time compensating for weaknesses in any of these areas. This might involve working on improving weak areas to become better adapted to the needs of a particular environment, or choosing to work in an environment that values the individual’s particular strengths. For example, a person with highly developed analytical and practical abilities, but with less well-developed creative abilities, might choose to work in a field that values technical expertise but does not require a great deal of imaginative thinking. Conversely, if the chosen career does value creative abilities, the individual can use his or her analytical strengths to come up with strategies for improving this weakness. Thus, a central feature of the triarchic theory of successful intelligence is adaptability-both within the individual and within the individual’s socio-cultural context (Cianciolo & Sternberg, 2004).

2.4.4 Evaluation

The triarchic theory of intelligence provides a useful way of understanding human intelligence. It seems to capture important aspects of intelligence not captured by more conventional theories. It also differs from the theories of Howard Gardner, which emphasise nine independent multiple intelligences (such as linguistic and musical intelligence), and from the theory of emotional intelligence. The triarchic theory emphasises processes of intelligence, rather than domains of intelligence, as in Gardner’s theory. It also views emotions as distinct from intelligence. Eventually, a theory may be proposed that integrates the best elements of all existing theories.

Triarchic theory has also been criticized by the psychologists. Gottfredson, (2003) criticized the unempirical nature of triarchic theory and argued that it is absurd to assert that traditional intelligence tests are not measuring practical intelligence when they show a moderate correlation with income, especially at middle age when individuals have had a chance to reach their maximum career potential. It is also claimed that what Sternberg calls practical intelligence is not a broad aspect of cognition at all but simply a specific set of skills people learn to cope with a specific environment (task specific knowledge). According to Das (2004), the major difficulty in Sternberg's theory is "in translating them to psychometric instruments for the measurement of cognitive abilities" (p. 12). As for the creative component of Sternberg's model, a study questions whether it's meaningful to treat creativity as a cognitive ability separate from analytical intelligence, but instead finds that creativity is simply the product of a high intelligence score.

Self Assessment Questions

- 1) Discuss Sternberg's triarchic theory of intelligence.

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- 2) Explain the three subtheories or facets of the triarchic theory of intelligence.

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- 3) How is triarchic theory of intelligence different from the construct-of-intellect theory?

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2.5 LET US SUM UP

According to Guilford intelligence is not one monolithic, global attribute but a combination of multiple abilities. He believed that there were many relatively independent mental ability factors. Guilford applied his factor analytic methodology to study these mental abilities. In 1956, the first version of the

Structure-of-Intellect (SOI) model was presented, which was subsequently revised by him in 1977. The SOI model includes a Content dimension, Products dimension, and Operations dimension. It is represented as a cube with each of the three dimensions occupying one side. Each ability is defined by a conjunction of the three categories, occupying one cell in the three-dimensional figure. There are five categories of content including visual, auditory, symbolic, semantic, and behavioural. Six categories exist in the products dimension including units, classes, relations, systems, transformation, and implications. The five kinds of operations include cognition, memory recording, memory retention, divergent production, convergent production, and evaluation. Guilford's SOI Theory is an open system such that it allows for newly discovered categories to be added in any of three directions. Many of the abilities are believed to be correlated with each other. The $5 \times 6 \times 5$ model of Guilford provides 150 possible abilities, with over 100 having been empirically verified. The model also suggests where new abilities may be discovered based on existing abilities.

The theory of multiple intelligences was developed in 1983 by Dr. Howard Gardner. It suggests that the traditional notion of intelligence, based on I.Q. testing, is far too limited. Instead, Gardner proposed nine different intelligences to account for a broader range of human potential in children and adults. Gardner's Theory of Multiple Intelligences proposes that people use seven (or nine) relatively autonomous intellectual capacities to approach problems and create products. These include linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, interpersonal, intrapersonal, naturalistic and existential intelligences. He suggests that "although they are not necessarily dependent on each other, these intelligences seldom operate in isolation. Every normal individual possesses varying degrees of each of these intelligences, but the ways in which intelligences combine and blend are as varied as the faces and the personalities of individuals."

Sternberg's triarchic theory of intelligence consists of three subtheories: (i) the componential subtheory, which outlines the structures and mechanisms that underlie intelligent behaviour categorised as metacognitive, performance, or knowledge acquisition components, (ii) the experiential subtheory that proposes intelligent behaviour be interpreted along a continuum of experience from novel to highly familiar tasks/situations, and (iii) the contextual subtheory, which specifies that intelligent behaviour be defined by the socio-cultural context in which it takes place and involves adaptation to the environment, selection of better environments, and shaping of the present environment. According to Sternberg, a complete explanation of intelligence entails the interaction of these three subtheories. The componential subtheory specifies the potential set of mental processes that underlie behaviour (i.e., how the behaviour is generated), while the contextual subtheory relates intelligence to the external world in terms of what behaviours are intelligent and where. The experiential subtheory addresses the relationship between the behaviour in a given task/situation and the amount of experience of the individual in that task/situation.

2.6 UNIT END QUESTIONS

- 1) How does theory of multiple intelligences differ from unitary theory of intelligence?
- 2) Highlight the important features of construct-of-intellect theory of Guilford.

- 3) Are the nine kinds of intelligence proposed by Gardner interrelated?
- 4) Evaluate the importance of Gardner's approach in the explanation of intelligence.
- 5) How is Gardner's theory different from Guilford's construct-of-intellect theory?
- 6) Critically evaluate Sternberg's triarchic theory of intelligence.
- 7) Explain the three subtheories or facets of triarchic theory of intelligence
- 8) How is triarchic theory of intelligence different from the construct-of-intellect theory?

2.7 GLOSSARY

Artificial intelligence	:	A branch of science that studies the capacity of computers to demonstrate performing that if, it were produced by human beings, would be described as showing the intelligence.
Contents dimension	:	In Guilford's three dimensional theory of intelligence construction of intellect includes five broad areas of information to which the human intellect applies the six operations.
Factor analysis	:	Mathematical procedure, involving correlations, for sorting trait terms or test responses into clusters or factors. It identifies items that are homogeneous or internally consistent.
Intelligence test	:	A standardised psychological test of general mental ability.
Intelligence quotient (IQ)	:	An index of individual's development determined by dividing his mental age by his chronological age and multiplying the result by 100.
Operations dimension	:	In Guilford's three dimensional theory of intelligence construction of intellect includes six operations or general intellectual processes.
Products dimension	:	In Guilford's three dimensional theory of intelligence construction of intellect product dimension contains results of applying particular operations to specific contents. The SI model includes six products, in increasing complexity:

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UNIT 3 MEASUREMENT OF INTELLIGENCE

Structure

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- 3.1 Objectives
- 3.2 Theoretical Background of Measurement of Intelligence
 - 3.2.1 General Factor Theories
 - 3.2.2 Multi-factor Theories
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 - 3.2.2.2 Guilford's Model of Structure of Intellect
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3.0 INTRODUCTION

Need to measure intelligence arise to trap individual differences in general mental ability for a variety of purposes, such as academic classification, occupational counseling and personnel selection. Intelligence tests can be defined as a test to evaluate general level of cognitive functions and intellectual ability. In this unit we will discuss theoretical background and evolution of intelligence tests. We will also present an account of some of the widely used intelligence tests. The unit will be concluded by highlighting the issues related to intelligence testing.

3.1 OBJECTIVES

After reading this unit, you will be able to:

- Define intelligence tests;
- Describe the concepts of IQ and deviation IQ;
- Explain the theoretical background of measurement of intelligence;
- Elucidate the history of intelligence tests;
- Explain the types of intelligence tests; and
- Describe various widely used intelligence tests.

3.2 THEORETICAL BACKGROUND OF MEASUREMENT OF INTELLIGENCE

Intelligence tests differ a lot in the content and the way of measurement. These differences arrive from the theoretical background they follow and also from defining intelligence. Therefore, before discussing specific intelligence tests we must understand the theoretical background they follow.

3.2.1 General Factor Theories

On the basis of factor analysis of scores on a number of tests, general factor theories claim that intelligence is basically a general intellectual capacity which is common for a number or all of activities. One of such theories was proposed by Charles Spearman (1904) who claimed that there is a *general* or *g-factor* which is essentially common in all the intellectual activities. Spearman suggested that two tests truly measuring *g* would account for high positive correlation. In a revision of the theory, he proposed a number of *specific* or *s-factors* required for specific activities. Tests measuring distinct *s-factors* should account for zero-correlation.

Jensen (1998) further advocated this viewpoint by arguing that *g-factor* is manifested in behaviour in a number of ways and can be tested by almost unlimited variety of conceptually independent items. Therefore, a number of distinct tests can be constructed to measure *g-factor* with completely different form and content of the items. However, Jensen's idea that *g* is largely inherited and rarely influenced by the environment was highly controversial and criticized.

Binet and Simon (1916) also conceptualised intelligence as a general intellectual capacity. But he differed from Spearman and Jensen and proposed that this can be measured by a variety of test items measuring several discrete abilities. An integrated score, termed as intelligence quotient (IQ), on all of these ability tests would account a true measurement of intelligence. According to Binet a general intellectual capacity consists of the abilities of (a) abstract reasoning (b) comprehension (c) clear direction of thought (d) purposeful thinking and (e) self-corrective judgment.

3.2.2 Multi-factor Theories

Contrary to Spearman, multi-factor theories neglect the existence of *g-factor* and state that intelligence is not an expression of innumerable highly specific

factors, nor is it the expression primarily of a general factor that pervades all mental activities. Such theories describe intelligence on the basis of groups of traits or factors.

3.2.2.1 Thurstone's Primary Mental Abilities/Group Factor Theory

The analysis of interpretation of Spearman's and others' general factor theories led Thurstone to conclude that 'certain' mental operations have in common a 'primary' factor that gives them psychological and functional unity and that differentiates them from other mental operations. These mental operations then constitute a group. A second group of mental operation has its own unifying primary factor, and so on. In other words, there are a number of groups of mental abilities, each of which has its own primary factor, giving the group a functional unity and cohesiveness. Each of these primary factors is said to be relatively independent of the others.

Thurstone has given the following seven primary factors:

- i) The Number Factor (N) refers to the ability to do rapid and accurate numerical calculations.
- ii) The Verbal Factor (V) refers to the ability of verbal comprehension.
- iii) The Space Factor (S) is involved in a task requiring manipulation of the imaginary objects in space.
- iv) Memory (M) involves ability to memorize quickly.
- v) Word Fluency (W) refers to the ability to think of isolated words at a rapid rate.
- vi) Reasoning (R) refers to the ability to discover a rule or principle involved in a series or groups of letters.
- vii) Perceptual Speed (P) is the ability to note visual details rapidly.

Based on these factors Thurstone constructed a new test of intelligence known as "Test of Primary Mental Abilities (PMA)."

3.2.2.2 Guilford's Model of Structure of Intellect

Guilford (1967) proposed a three dimensional structure of intellect model. According to Guilford every intellectual task can be classified according to its (1) content, (2) the mental operation involved and (3) the product resulting from the operation. He further classified content into five categories, namely, visual, auditory, symbolic, semantic and behavioural. He classified operations into five categories, namely, cognition, memory retention, memory recording, Divergent production, Convergent production and evaluation. He classified products into six categories, namely, units, classes, relations, systems, transformations and implications.

3.2.2.3 Gardener's Theory of Multiple Intelligences

Howard Gardner in his book "Frames of Mind: The Theory of Multiple Intelligence" (1983), puts forth a new and different view of human intellectual competencies. He argues boldly and cogently that we are all born with potential to develop a multiplicity of Intelligence, most of which have been overlooked in our testing society, and all of which can be drawn upon to make us competent individuals. The multiple intelligence theory states that people possess eight types

of intelligence: (i) Linguistic, (ii) Logical, (iii) Spatial, (iv) Musical, (v) Motor ability, (vi) Interpersonal, (vii) Intrapersonal and (viii) Naturalistic intelligence.

3.2.2.4 Sternberg's Triarchic Theory

Psychologist Robert Sternberg (1985) has constructed a three-pronged or triarchic theory of intelligence. The Three types are:

- i) Analytical Intelligence is what we generally think of as academic ability. It enables us to solve problems and to acquire new knowledge. Problem-solving skill includes encoding information, combining and comparing pieces of information and generating a solution.
- ii) Creative Intelligence is defined by the abilities to cope with novel situations and to profit from experience. The ability to quickly relate novel situations to familiar situations (that is, to perceive similarities and differences) fosters adaptation. Moreover, as a result of experience, we also become able to solve problems more rapidly.
- iii) Practical Intelligence enables people to adapt to the demands of their environment. For example, keeping a job by adapting one's behaviour to the employer's requirements is adaptive. But if the employer is making unreasonable demands, reshaping the environment (by changing the employer's attitudes) or selecting an alternate environment (by finding a more suitable job) is also adaptive.

3.2.2.5 Vernon's Hierarchical Theory

Vernon's description of different levels of intelligence may fill the gaps between two extreme theories, the two-factor theory of Spearman, which did not allow for the existence of group factors, and the multiple-factor theory of Turstone, which did not allow a "g" factor. Intelligence can be described as comprising abilities at varying levels of generality:

- i) The highest level: "g" (general intelligence) factor with the largest source of variance between individuals. (Spearman)
- ii) The next level: major group factors such as verbal-numerical-educational (v.ed) and practical-mechanical-spatial-physical (k.m.) ability.
- iii) The next level: minor group factors are divided from major group factors.
- iv) The bottom level: "s"(specific) factor. (Spearmen)

Beginning in 1969, Vernon became increasingly involved in studying the contributions of environmental and genetic factors to intellectual development. Vernon continued to analyse the effects of genes and the environment on both individual and group difference in intelligence. He concludes that individual difference in intelligence are approximately 60 percent attributable to genetic factors, and that there is some evidence implicating genes in racial group differences in average levels of mental ability.

3.3 HISTORY OF MEASUREMENT OF INTELLIGENCE

At the time of early development of discipline psychologists were much more interested in searching of generalised principles of human behaviour and

subsequently formulating universal theories. Measurement of individual differences received attention very late in the nineteenth century.

3.3.1 Galton and Cattell

The first institutional effort to measure individual differences came from the British biologist Sir Francis Galton who administered simple tests of visual discrimination, determining highest audible pitch and kinesthetic discrimination. He thought that intelligence could be measured by the tests of sensory discrimination. He believed that the ability to discriminate among heat, cold and pain could discriminate the intelligent persons from the mentally retarded ones.

The term 'mental test' was used first time in the psychological literature by the American psychologist James McKeen Cattell in 1890. He described a number of tests to measure intellectual level of persons which included measures of muscular strength, speed of movement, sensitivity to pain, keenness of vision and of hearing, weight discrimination, reaction time, memory etc.

3.3.2 Contribution of Alfred Binet

Alfred Binet (1857-1911) set out to develop a series of tasks designed to measure individual differences on the request of the French government due to the need for a reliable diagnostic system to identify children with mental retardation. The differences that he intended to delineate included a number of complex mental facilities, such as memory, imagery, imagination, attention, comprehension, aesthetic sentiment, moral sentiment, muscular strength, motor ability, and hand-eye coordination. Together with physician Theodore Simon, Binet created the Binet-Simon scale, which was published in 1905.

The 1905 Binet-Simon scale differed greatly from the scale that we use today. The original scale consisted of 30 pass/fail items. The tasks were also different from today's items and required a combination of mental and physical strategies to complete each task.

The major breakthrough of the Binet-Simon scale was the complexity of the tasks and the breadth of mental abilities measured. Furthermore, intelligence was finally able to be measured during a clinical interview, as opposed to in laboratories or by using physical measurements.

Although the Binet-Simon scale is quite antiquated with regard to today's intelligence scale standards, many current day innovations were derived from this scale. The concepts of strict administration, age-graded norms, and a rank order of items ranging from least to most difficult, are but a few. Furthermore, the inclusion of age-graded norms provided for the first estimate of mental age.

The first revision of the Binet scale was in 1908; however, the majority of the scale was left unchanged. By 1911, the scale was in its second revision and the age range had been extended through adulthood, as opposed to its previous use for the diagnosis of mental retardation in children. With the inclusion of adults, the scales needed to be rebalanced, which Binet did by including five items for each age level.

The abilities targeted by the 1911 edition were language, auditory processing, visual processing, learning and memory, and problem solving. By 1912, Lewis

M. Terman of Stanford University began revisions on the 1911 Binet scale which was published in 1916 and was entitled the *Stanford-Binet Intelligence Scale*.

The advantages that the Stanford-Binet had over other intelligence scales of the time were many. The first, and seemingly most simplistic, was that the 1916 version was the most comprehensive revision of Binet's original scale. The second, and perhaps the most important, was that the standardisation procedure used by Terman was the most rigorous of the time. The third advantage was the inclusion of an extensive manual, both for administration of the test as well as for use as a teaching aide for understanding the test.

3.3.3 The Concept of IQ

The most important development in the area of intelligence testing was adaptation of Stern's (1912) concept of an intelligence quotient in the Stanford-Binet Intelligence Scale. Stern put forth the notion that to derive an intelligence quotient (IQ) and Terman incorporated this concept into the 1916 version of Stanford-Binet Scale. To obtain the IQ a person's mental age is divided by his/her chronological or real age. This product is further multiplied by hundred to avoid decimal fractions.

$$IQ = \frac{\text{Mental Age}}{\text{Chronological Age}} \times 100$$

3.3.4 World War I and Army Personnel Selection

During World War I in 1917 a committee of American Psychological Association, under leadership of Robert M. Yerkes, prescribed the use of intelligence tests for rapid classification of army personnel. In view of this, American Army psychologists developed two tests: (i) Army Alpha and (ii) Army Beta. Both the tests were group tests in which the first was a language test, while the second was a non-language-performance test.

Self Assessment Questions

- 1) Describe the contributions of Galton and Cattell in the development of measurement of individual differences.

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- 2) Explain first Simon-Binet Test and its improvement over earlier tests.

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3) Illustrate the concept of IQ.

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3.4 MAJOR INTELLIGENCE TESTS

Intelligence tests are classified on several bases.

i) Individual and Group tests (Target)

ii) Verbal and Non verbal tests

Individual and Group Tests

The first of these classification, individual and group tests, is based on their administration. An individual test is one that can be administered only at one person at a time (Simon-Binet). During World War I rapid and mass classification of army personnel was required and such tests could not fulfil these needs. Therefore, group intelligence tests were developed which could be administered on a group of individuals at one go (Army Alpha and Army Beta).

Verbal / non verbal tests

Another classification of intelligence tests based on the form and content of the test items is verbal/paper-pencil tests and non-verbal/performance tests. Verbal tests use written language for its items and therefore, require the examinees to be literate. Items of performance tests do not use language at all and are manipulative in form and nature. Examinees are required to manipulate the items in a particular and desired manner. Hence, such tests can be effectively administered on illiterates, children and deaf persons also. Some of the performance tests claim to be suitably used at persons from different cultures and prefer to be called as culture-free, culture-fair, culture-reduced and cross-cultural tests.

3.4.1 Types of Intelligence Scales

There are many types of intelligence a few of which are presented below.

3.4.1.1 Stanford-Binet Test

Terman had revised the Stanford Binet with the help of Maud Merrill in 1937 as the *Revised Stanford-Binet Intelligence Scale*. The revision included two alternate forms, the L form and the M form, each with 129 items.

The third revision of the Stanford-Binet came after Terman's death in 1960 and was constructed primarily by Merrill. The *Stanford-Binet Intelligence Scale, Form L-M*, was different from its predecessor in that it included a deviation intelligence quotient with a normative mean of 100 and a standard deviation of 16. This

version also included the 142 most pertinent items from the two previous forms of the test (Roid, 2003).

The fourth revision of the Stanford-Binet, the Stanford-Binet Intelligence Scales (SB4) came in 1986 and retained much of the content of the Form L-M edition. The same age range was covered; many of the same items and tasks were retained, and the basal and ceiling procedures were quite similar.

The greatest advance of the fourth edition was that, like the fifth edition, the fourth edition was based on a hierarchical model of intelligence. The four main areas assessed were verbal reasoning, abstract/visual reasoning, quantitative reasoning, and short-term memory. The fourth edition not only provided an overall intelligence quotient, but composite scores as well. Furthermore, to establish a basal level, the Vocabulary subtest of the fourth edition was used as a routing subtest, along with the subject's chronological age (Roid, 2003).

The latest version of the test, the Stanford-Binet Intelligence Scales–Fifth Edition (SB5) differs significantly from the SB4 with regard to theoretical structure, as the SB5 adheres rather strictly to the Cattell-Horn-Carroll (CHC) cognitive theory and the SB4 adheres to a less strict psychometric design.

The changes between the fourth and the fifth editions of the Binet scale included changes in the layout of the test, norm standards, and the underlying theoretical structure of the instrument. (Roid, 2003).

The SB5 is used to assess intellectual ability in individuals between the ages of two and 89 years, is individually administered, and contains 10 subscales. The three areas assessed by the SB5 are: general cognitive functioning, verbal and nonverbal intelligence and five CHC factors formed into groups along verbal/nonverbal measures. The nonverbal portion of the SB5 accounts for 50% of the test and ranges across all factors, which is unique to the SB5 among cognitive batteries.

The five CHC factors that the SB5 measures are Fluid Reasoning, Knowledge, Quantitative Reasoning, Visual-Spatial Processing, and Working Memory. Together, the ten subtests yield an overall estimate of cognitive functioning, which is the Full Scale Intelligence Quotient (Roid, 2003) and nonverbal contrast, an abbreviated version, and a nonverbal form of the test.

Composites and subtests of the SB5

The SB5 is comprised of 5 composite scores each with a verbal and a nonverbal test-let, for a total of 10 subtests. Structure of the test is given below:

Factor Indices	Domains	
	Nonverbal	Verbal
Fluid Reasoning	<i>Activity: Object-Series/ Matrices</i> Requires the ability to solve novel figural problems and identify sequences of pictured objects or matrix-type figural and geometric patterns.	<i>Activities: Early Reasoning, Verbal Absurdities, Verbal Analogies</i> Requires the ability to analyse and explain, using deductive and inductive reasoning, problems involving cause effect connections in pictures, classification of objects, absurd statements, and interrelationships among words.

Knowledge	<i>Activity: Procedural Knowledge, Picture Absurdities</i> Requires knowledge about common signals, actions, and objects and the ability to identify absurd or missing details in pictorial material.	<i>Activity: Vocabulary</i> Requires the ability to apply accumulated knowledge of concepts and language and to identify and define increasingly difficult words.
Quantitative Reasoning	<i>Activity: Nonverbal Quantitative Reasoning</i> Requires the ability to solve increasingly difficult pre-mathematic, arithmetic, algebraic, or functional concepts and relationships depicted in illustrations.	<i>Activity: Verbal Quantitative Reasoning</i> Requires the ability to solve increasingly difficult mathematical tasks involving basic numerical concepts, counting, and word problems.
Visual-Spatial Processing	<i>Activity: Form Board, Form Patterns</i> Requires the ability to visualise and solve spatial and figural problems presented as “puzzles” or complete patterns by moving plastic pieces into place.	<i>Activity: Position and Direction</i> Requires the ability to identify common objects and pictures using common visual-spatial terms such as “behind” and “farthest left,” explain spatial directions for reaching a pictured destination, or indicate direction and position in relation to a reference point
Working Memory	<i>Activity: Delayed Response, Block Span</i> Requires the ability to sort visual information in short-term memory and to demonstrate short-term and working memory skills for tapping sequences of blocks.	<i>Activity: Memory for Sentences, Last Word</i> Requires the ability to demonstrate short-term and working memory for words and sentences and to store, sort, and recall verbal information in short-term memory.

Scoring and Interpretation

The SB5 can be hand-scored or scored with optional scoring software. At the most granular level of the norm-referenced scores are the ten subtest scores (scaled scores have a mean of 10, SD=3, score range 1-19).

These subtest scores combine to form four types of composite scores: factor index, domain, abbreviated, and full scale (each with scaled score means of 100, SD=15, score range 40-160). Two subtests (one verbal, the other its nonverbal complement) combine to form each factor index.

There are two domain scales: Nonverbal IQ (combines the five nonverbal subtests) and Verbal IQ (combines the five verbal subtests). Two routing subtests combine to form the Abbreviated Battery IQ. Finally, the Full Scale IQ combines all ten subtests.

The Change-Sensitive Scores (CSSs) use item response theory scaling to convert the raw score totals on the composite scales described above into criterion-referenced levels of ability. These scales, as with the norm-referenced scores,

have excellent measurement properties. Because the CSSs reference absolute levels of ability, they provide a means to compare changes in an individual's scores over time. Scores range from the 2-year-old level (about 430) to the adult level (about 520). All of the SB5 items have been calibrated to this scale, and the difficulty of each item has a location along that scale. The scores will be particularly useful for the evaluation of extreme performance levels.

The SB5 also offers age-equivalent scores derived from CSSs, along with a CSS-based abbreviated battery score making use of raw scores from the Nonverbal Reasoning and Verbal Knowledge subtests. Finally, the Interpretive Manual describes a hand-scoring procedure for deriving an extended Full Scale IQ score that allows for scores below 40 and above 160. A variety of interpretive frameworks, such as Examiner's Manual, Interpretive Manual, or the SB5 Scoring Pro software, can be applied to the results of this test.

3.4.1.2 Wechsler Intelligence Scales

The first Wechsler intelligence scale came in 1939. After that Wechsler scales have gone through several successive revisions for three different categories: (i) for adults (16-90 years), (ii) for school-going children (6-16 years) and (iii) for pre-schoolers (2½-7 years). Year-wise development of these scales is given below:

Wechsler Adult Intelligence Scale (WAIS)	Wechsler Intelligence Scale for Children (WISC)	Wechsler Preschool and Primary Scale of Intelligence
Wechsler-Bellevue-I:1939	Wechsler-Bellevue-II: 1946	WPPSI: 1967
WAIS: 1955	WISC: 1949	WPPSI-R: 1989
WAIS-R: 1981	WISC-R: 1974	WPPSI-III: 2002
WAIS-III: 1997	WISC-III: 1991	
WAIS-IV: 2008	WISC-IV: 2003	

Since its publication, the Wechsler intelligence scales have been the most used instruments among clinical and school psychologists for assessing the cognitive abilities of children, adolescents and adults. Wechsler viewed the construct of intelligence not only as a global entity but also as an aggregate of specific abilities that are qualitatively different. Intelligence is global because it characterises the individual's behaviour as a whole.

3.4.2 Wechsler's Intelligence Scales

Wechsler (1944) defined intelligence in a general behavioural term as the capacity to act purposefully, to think rationally and to deal effectively with the environment. He also believed that intelligence is specific because it is made up of elements or abilities that are qualitatively different and can be measured by a variety of tests. Factor analytic researches of intelligence test scores also suggest that intelligence is composed of specific abilities that form clusters of higher order ability domains.

3.4.2.1 Structure of WAIS-IV

The current version of the test, the WAIS-IV, which was released in 2008, is composed of 10 core subtests and five supplemental subtests, with the 10 core subtests comprising the Full Scale IQ. With the new WAIS-IV, the verbal/performance subscales from previous versions were removed and replaced by

the index scores. The General Ability Index (GAI) was included, which consists of the Similarities, Vocabulary and Information subtests from the Verbal Comprehension Index and the Block Design, Matrix Reasoning and Visual Puzzles subtests from the Perceptual Reasoning Index. The GAI is clinically useful because it can be used as a measure of cognitive abilities that are less vulnerable to impairment.

Indices and scales

There are four index scores representing major components of intelligence:

- Verbal Comprehension Index (VCI)
- Perceptual Reasoning Index (PRI)
- Working Memory Index (WMI)
- Processing Speed Index (PSI)

Two broad scores are also generated, which can be used to summarize general intellectual abilities:

- Full Scale IQ (FSIQ), based on the total combined performance of the VCI, PRI, WMI, and PSI
- General Ability Index (GAI), based only on the six subtests that comprise the VCI and PRI

3.4.2.2 Subtests

The Verbal Comprehension Index includes four tests:

- Similarities: Abstract verbal reasoning (e.g., “In what way are an apple and a pear alike?”)
- Vocabulary: The degree to which one has learned, been able to comprehend and verbally express vocabulary (e.g., “What is a guitar?”)
- Information: Degree of general information acquired from culture (e.g., “Who is the president of Russia?”)
- Comprehension [Supplemental]: Ability to deal with abstract social conventions, rules and expressions (e.g., “What does *Kill 2 birds with 1 stone* metaphorically mean?”)

The Perceptual Reasoning Index comprises five tests

- Block Design: Spatial perception, visual abstract processing and problem solving
- Matrix Reasoning: Nonverbal abstract problem solving, inductive reasoning, spatial reasoning
- Visual Puzzles: non-verbal reasoning
- Picture Completion [Supplemental]: Ability to quickly perceive visual details
- Figure Weights [Supplemental]: quantitative and analogical reasoning

The Working Memory Index is obtained from three tests

- Digit span: attention, concentration, mental control (e.g., Repeat the numbers 1-2-3 in reverse sequence)
- Arithmetic: Concentration while manipulating mental mathematical problems (e.g., “How many 45-cent stamps can you buy for a dollar?”)

- Letter-Number Sequencing [Supplemental]: attention and working memory (e.g., Repeat the sequence Q-1-B-3-J-2, but place the numbers in numerical order and then the letters in alphabetical order)

3.4.2.3 The Processing Speed Index Includes Three Tests

- Symbol Search: Visual perception, speed
- Coding: Visual-motor coordination, motor and mental speed
- Cancellation [Supplemental]: visual-perceptual speed

Interpretation

Wechsler scales use an innovative deviation IQ score for interpretation of an individual's score. The deviation IQ is based on standard scores computed with the same distributional characteristics at all ages and makes comparison among peers more meaningful and the interpretation more straightforward. The WAIS-IV was standardized on a sample of 2,200 people in the United States ranging in age from 16 to 90. An extension of the standardisation has been conducted with 688 Canadians in the same age range. The median Full Scale IQ is centered at 100, with a standard deviation of 15. In a normal distribution, the IQ range of one standard deviation above and below the mean (i.e., between 85 and 115) is where approximately 68% of all adults would fall.

3.4.3 Kaufman Assessment Scales

The first Kaufman Scale, Kaufman Assessment Battery for Children (K-ABC; Kaufman & Kaufman, 1983) was developed in the late 1970s and early 1980s and was published in 1983, during a time when IQ was largely a Wechsler-Binet monopoly. This scale intended to bridge the gap between theories of intelligence and measures of intelligence. Two important tests of this series are given below:

3.4.3.1 Kaufman Assessment Battery for Children

The second revision of K-ABC, the KABC-II was published in 2004 for the Age range of 3 to 18 years. This test measures learning (long-term retrieval), sequential processing (short-term memory), simultaneous processing (visualisation), planning (fluid ability) and verbal knowledge (crystallised ability). The KABC-II is founded in two theoretical models: Luria's (1973) neuropsychological model, featuring three blocks, and the Cattell-Horn-Carroll (CHC) approach to categorising specific cognitive abilities (Carroll, 1997). The KABC-II yields a separate global score for each of these two theoretical models: The global score measuring general mental processing ability from the Luria perspective is the Mental Processing Index (MPI), and global score measuring general cognitive ability from the CHC perspective is the Fluid-Crystallised Index (FCI). The key difference between these two global scores is that the MPI (Luria's theory) *excludes* measures of acquired knowledge, whereas the FCI (CHC theory) *includes* measures of acquired knowledge. Only one of these two global scores is computed for any examinee. Prior to testing a client, examiners choose the interpretive system (i.e., Luria or CHC) that best fits with both their personal orientation and the reason for referral. Deciding which interpretive system to use will dictate which global score is reported and also whether measures of acquired knowledge are included from the core battery. The authors of the KABC-II clearly state in the manual that "the CHC model should generally be the model of choice, except in cases where the examiner believes that including measures

of acquired knowledge/crystallised ability would compromise the validity of the Fluid-Crystallised Index.” In those cases, the Luria global score (MPI) is preferred.

3.4.3.2 Structure of the KABC-II

The complete scale description of KABC-II is given in the table below:

Scales	Subtests Description
Sequential/Gsm	
Word Order	The child touches a series of silhouettes of common objects in the same order as the examiner said the names of the objects; more difficult items include an interference task (colour naming) between the stimulus and response
Number Recall	The child repeats a series of numbers in the same sequence as the examiner said them, with series ranging in length from two to nine numbers; the numbers are single digits, except that 10 is used instead of 7 to ensure that all numbers are one syllable.
Hand Movements	The child copies the examiner’s precise sequence of taps on the table with the fist, palm, or side of the hand.
Simultaneous/Gv	
Rover	The child moves a toy dog to a bone on a checkerboard like grid that contains obstacles (rocks and weeds) and tries to find the “quickest” path—the one that takes the fewest moves.
Triangles	For most items, the child assembles several identical rubber triangles (blue on one side, yellow on the other) to match a picture of an abstract design; for easier items, the child assembles a different set of colourful plastic shapes to match a model constructed by the examiner.
Conceptual Thinking	The child views a set of four or five pictures and identifies the one picture that does not belong with the others; some items present meaningful stimuli and others use abstract stimuli.
Face Recognition	The child attends closely to photographs of one or two faces that are exposed briefly and then selects the correct face or faces, shown in a different pose, from a group photograph.
Gestalt Closure	The child mentally fills in the gaps in a partially completed inkblot drawing and names (or describes) the object or action depicted in the drawing.
Block Counting	The child counts the exact number of blocks in various pictures of stacks of blocks; the stacks are configured such that one or more blocks is hidden or partially hidden from view.

Planning/Gf	
Pattern Reasoning	The child is shown a series of stimuli that form a logical, linear pattern, but one stimulus is missing; the child completes the pattern by selecting the correct stimulus from an array of four to six options at the bottom of the page (most stimuli are abstract, geometric shapes, but some easy items use meaningful stimuli).
Story Completion	The child is shown a row of pictures that tell a story, but some of the pictures are missing. The child is given a set of pictures, selects only the ones that are needed to complete the story, and places the missing pictures in their correct location.
Learning/Glr	
Atlantis	The examiner teaches the child the nonsense names for fanciful pictures of fish, plants, and shells; the child demonstrates learning by pointing to each picture (out of an array of pictures) when it is named.
Atlantis Delayed	The child demonstrates delayed recall of paired associations learned about 15–25 minutes earlier during Atlantis by pointing to the picture of the fish, plant, or shell that is named by the examiner.
Rebus Learning	The examiner teaches the child the word or concept associated with each particular rebus (drawing), and the child then “reads” aloud phrases and sentences composed of these rebuses.
Rebus Learning Delayed	The child demonstrates delayed recall of paired associations learned about 15–25 minutes earlier during Rebus by “reading” phrases and sentences composed of those same rebuses.
Knowledge/Gc	
Riddles	The examiner provides several characteristics of a concrete or abstract verbal concept, and the child has to point to it (early items) or name it (later items).
Expressive Vocabulary	The child provides the name of a pictured object.
Verbal Knowledge	The child selects from an array of six pictures the one that corresponds to a vocabulary word or answers a general information question.

(Source: *KABC-II Manual*; Kaufman & Kaufman, 2004).

3.5 STANDARD SCORES AND SCALED SCORES

The KABC-II's two global scores, the MPI and FCI, both are standard scores with a mean of 100 and a standard deviation (SD) of 15. However, only *one* of these two global scores is computed and interpreted for any child or adolescent who is evaluated, based on the examiner's choice of the Luria or CHC model for that individual. Like the MPI and FCI, the KABC-II Nonverbal Index is also a

standard score with a mean of 100 and SD of 15. The five additional KABC-II scales offered for ages 4–18 each have a mean of 100 and SD of 15 (but only the MPI and FCI are offered at age 3). All KABC-II subtests have a mean of 10 and SD of 3. The Core subtest standard scores contribute to the scales, but the Supplementary scaled scores do not (except for the special Nonverbal scale).

3.5.1 The Kaufman Adolescent and Adult Intelligence Test

The Kaufman Adolescent and Adult Intelligence Test (KAIT) was developed by Alan S. Kaufman and Nadeen L. Kaufman in 1993 and is an individually administered intelligence test for individuals ranging from 11 to 85-plus years of age. It has a strong theoretical base integrating Horn and Cattell's concept of fluid and crystallised intelligence, Luria and Golden's notion of frontal lobe planning ability, and Piaget's construct of formal operational thought. The test is comprised of crystallised scale (measuring concepts acquired from schooling and acculturation) and fluid scale measuring (ability to solve new problems). Core battery of test is composed of three subtests from each of the scales. The expanded battery is used with persons having neurological damage. For the persons with cognitive impairment, who cannot take the full battery, mental status test is administered to assess the person's attention and orientation.

Self Assessment Questions

- 1) Describe the development of Stanford-Binet Scales. Explain the structure and interpretation of SB5.

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- 2) What are the variants of Wechsler Scales? Describe the structure and interpretation of WAIS-IV.

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- 3) What are the theoretical bases of Kaufman Assessment Scales? Describe KABC-II and KAIT.

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3.6 LET US SUM UP

Intelligence tests measure individual differences in terms of cognitive functions and intellectual abilities. Some of the intelligence tests theoretically incline to measure a general intellectual ability and give an integrated intelligence score (IQ), while, other tests are focussed on measuring groups of factors for a variety of mental activities. Tests also differ in the ways of administration (individual and group tests) and form and nature of their items (verbal/paper-pencil tests and non-verbal/performance tests). Culture-free tests claim to be usable to the persons from different cultures. Modern intelligence testing started with Simon-Binet test in 1905. A series of revisions of the test has been published by Terman and the currently used version of the test is SB5. A number of variants of Wechsler scales have been most used instruments of cognitive assessment and very useful tool for clinical and neuro-psychological practitioners and researchers. The test introduced an innovative deviation IQ based on the standard scores. The currently used Kaufman assessment scales, KABC-II, is the most theoretically grounded and psychometrically rigorous test. The test is based on two theoretical models: Luria's neuropsychological model and the Cattell-Horn-Carroll (CHC) approach to categorising specific cognitive abilities. The provides separate global scores for each of these two theoretical models: The global score measuring general mental processing ability from the Luria perspective is the Mental Processing Index, and global score measuring general cognitive ability from the CHC perspective is the Fluid-Crystallised Index.

3.7 UNIT END QUESTIONS

- 1) Define intelligence tests and explain the theoretical background of measurement of intelligence.
- 2) Describe the history of intelligence tests and present an account of the concepts of IQ and deviation IQ.
- 3) Explain the types of intelligence tests with their relative advantages and disadvantages.
- 4) Describe the development of Simon-Binet tests. Also present a detailed account of SB5.
- 5) Provide a historical account of development of variants of Wechsler Scales. Describe the nature, structure and interpretation of WAIS-IV.
- 6) By explaining theoretical grounds of Kaufman's Scales present a complete description of structure and interpretation of KABC-II and KAIT.

3.8 GLOSSARY

Intelligence tests	: Tests defined as a test to evaluate general level of cognitive functions and intellectual ability.
General factor	: Factor which is essentially common in all the intellectual activities.
Specific factors	: Factors required for specific intellectual activities.
IQ	: Intelligence quotient is an integrated intelligence score obtained by dividing person's mental age by

his/her chronological or real age and further multiplied by hundred ($\{MA/CA\} \times 100$).

- Individual test** : Test that can be administered at only one person at a time.
- Group tests** : Tests that can be administered on a group of individuals at one go.
- Verbal/Paper-pencil tests** : Tests that use written language for its items.
- Non-verbal/ Performance tests** : Items of performance tests do not use language, are manipulative in nature and examinees are required to manipulate the items in a particular and desired manner.
- Culture-free tests** : Performance tests that claim to be suitably used at persons from different cultures.
- Deviation IQ** : The deviation IQ is based on standard scores computed with the same distributional characteristics at all ages and makes intra-group comparison meaningful.

3.9 SUGGESTED READINGS AND REFERENCES

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UNIT 4 CREATIVITY AND PROBLEM SOLVING

Structure

- 4.0 Introduction
- 4.1 Objectives
- 4.2 Creativity
 - 4.2.1 Meaning and Aspects of Creativity
 - 4.2.2 Investment and Confluence Theory of Creativity
 - 4.2.3 Aspects of Creativity
 - 4.2.4 Stages of Creativity
 - 4.2.5 Creativity and Intelligence
 - 4.2.6 Measurement of Creativity
- 4.3 Problem Solving
 - 4.3.1 Terms Related to Problem Solving
 - 4.3.2 Typologies of Problems
 - 4.3.3 Stages of Problem Solving
 - 4.3.4 Strategies of Problem Solving
 - 4.3.4.1 Algorithms
 - 4.3.4.2 Heuristics
 - 4.3.5 Factors Affecting Problem Solving
- 4.4 Let Us Sum Up
- 4.5 Unit End Questions
- 4.6 Glossary
- 4.7 Suggested Readings and References

4.0 INTRODUCTION

Human being is exceptionally blessed with the higher level thinking abilities of creativity and problem solving. Such activities require use of already stored information along with the information concurrently received from the environment. A thorough account of these multi-step processes will be presented in this unit. First of all, we will discuss meaning, aspects and stages of creativity. This will be followed by a description of measurement of creativity and its relationship with intelligence. We will also discuss meaning, stages and strategies of problem solving. Finally, factors affecting problem solving will be discussed.

4.1 OBJECTIVES

After reading this unit, you will be able to:

- Explain meaning, aspects and stages of creativity;
- Describe the tests to measure creativity and relate it with intelligence;
- Explain meaning, stages and strategies of problem solving; and
- Analyse the factors affecting problem solving.

4.2 CREATIVITY

The most advanced thought process, creativity, involves production of uncommon and novel ideas that are highly relevant to the situation. Creativity is defined as something different from intelligence and as a parallel construct to intelligence, but it differs from intelligence in that it is not restricted to cognitive or intellectual functioning or behaviour. Instead, it is concerned with a complex mix of motivational conditions, personality factors, environmental conditions, chance factors, and even products (Michalko, 1998).

4.2.1 Meaning and Aspects of Creativity

Creativity is a goal directed thinking which is unusual, novel and useful. Many of such creative thinking become so important that they influence the whole human civilisation and are called as historical creativity. The Mona Lisa, the laws of thermodynamics, the laws of motion, the theory of relativity are some of the ideas that were never thought before and changed the human civilisation altogether in a great way in their respective spheres of life. Although we can accept its existence and importance, it has been a highly difficult task for the researchers to define creativity.

Newell, Shaw and Simon (1963) have explained the nature of creativity on the basis of following four criteria:

- a) Novelty and usefulness
- b) Rejects previously accepted ideas
- c) Requires intense motivation and persistence
- d) Results from organising the unclear situation in a coherent, clear and new way.

Sternberg (2006) reports five commonalities in the research of creativity. These are:

- 1) Creativity involves thinking that aims at producing ideas or products that are relatively novel and that are, in some respect, compelling.
- 2) Creativity has some domain-specific and domain-general elements in the sense that it needs some specific knowledge, but there are certain elements of creativity that cut across different domains.
- 3) Creativity is measureable, at least to some extent.
- 4) Creativity can be developed and promoted.
- 5) Creativity is not highly rewarded in practice, as it is supposed to be in theory.

Sternberg and Lubart (1999) define creativity as the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e. useful concerning tasks constraints).

Runco (2007) categorised these definitions of creativity as involving the creation of something new and useful and calls them as “products definitions” of creativity. However, he thought that creative thinking did not essentially require tangible creative products; rather the process should be more focused in defining creativity.

Studies in cognitive psychology have tried to understand the process of creative thinking. These researches assumed that creativity is just extraordinary results of ordinary processes (Smith, Ward & Finke 1995). The process of creativity is thought to have following four characteristics:

- 1) It is imaginative involving imagination, since it is the process of generating something original.
- 2) It is purposeful, that is, creativity is imagination put into action towards an end.
- 3) It produces something original in relation to one's own previous work, to their peer group or to anyone's previous output in a particular field.
- 4) It has value in respect to the objective it was applied for. Creativity involves not only the generation of ideas, but also evaluation of them, and deciding which one is the most adequate one.

Beghetto and Kaufman (2007) conceptualised creativity in three different ways. They defined creativity as novel and personally meaningful interpretation of experiences, actions, and events. However, the novelty and meaningfulness of these interpretations need not require to be original or (even meaningful) to others. Indeed, the judgment of novelty and meaningfulness that constitutes creativity is an intrapersonal judgment. This intrapersonal judgment is what distinguishes creativity from other forms of creative expressions.

There are two types of creativity (i) little-c (or everyday) creativity and (ii) Big-C (or eminent) creativity. The latter two forms of creativity rely on interpersonal and historical judgments of novelty, appropriateness, and lasting impact.

4.2.2 Investment and Confluence Theory of Creativity

Sternberg (2006) has proposed investment and confluence theory to understand creativity. According to the investment theory, creativity requires a confluence of six distinct but interrelated resources: intellectual abilities, knowledge, styles of thinking, personality, motivation, and environment. Although levels of these resources are sources of individual differences, often the decision to use a resource is a more important source of individual differences.

Intellectual skills: Three intellectual skills are particularly important: (a) the synthetic skill to see problems in new ways and to escape the bounds of conventional thinking, (b) the analytic skill to recognise which of one's ideas are worth pursuing and which are not, and (c) the practical-contextual skill to know how to persuade others of—to sell other people on—the value of one's ideas. The confluence of these three skills is also important. Analytic skills used in the absence of the other two skills results in powerful critical, but not creative, thinking. Synthetic skill used in the absence of the other two skills results in new ideas that are not subjected to the scrutiny required to improve them and make them work. Practical-contextual skill in the absence of the other two skills may result in societal acceptance of ideas not because the ideas are good, but rather, because the ideas have been well and powerfully presented.

Knowledge: On the one hand, one needs to know enough about a field to move it forward. One cannot move beyond where a field is if one does not know where it is. On the other hand, knowledge about a field can result in a closed and

entrenched perspective, resulting in a person's not moving beyond the way in which he or she has seen problems in the past. Knowledge thus can help, or it can hinder creativity.

Thinking styles: Thinking styles are preferred ways of using one's skills. In essence, they are decisions about how to deploy the skills available to a person. With regard to thinking styles, a legislative style is particularly important for creativity, that is, a preference for thinking and a decision to think in new ways. This preference needs to be distinguished from the ability to think creatively: Someone may like to think along new lines, but not think well, or vice versa. It also helps to become a major creative thinker, if one is able to think globally as well as locally, distinguishing the forest from the trees and thereby recognising which questions are important and which ones are not.

Personality: Numerous research investigations have supported the importance of certain personality attributes for creative functioning. These attributes include, but are not limited to, willingness to overcome obstacles, willingness to take sensible risks, willingness to tolerate ambiguity, and self-efficacy. In particular, buying low and selling high typically means defying the crowd, so that one has to be willing to stand up to conventions if one wants to think and act in creative ways. Often creative people seek opposition; that is, they decide to think in ways that countervail how others think. Note that none of the attributes of creative thinking is fixed. One can decide to overcome obstacles, take sensible risks, and so forth.

Motivation: Intrinsic, task-focused motivation is also essential to creativity. The research of Amabile (1983) and others has shown the importance of such motivation for creative work and has suggested that people rarely do truly creative work in an area unless they really love what they are doing and focus on the work rather than the potential rewards. Motivation is not something inherent in a person: One decides to be motivated by one thing or another. Often, people who need to work in a certain area that does not particularly interest them will decide that, given the need to work in that area, they had better find a way to make it interest them. They will then look for some angle on the work they need to do that makes this work appeal to rather than bore them.

Environment: Finally, one needs an environment that is supportive and rewarding of creative ideas. One could have all of the internal resources needed to think creatively, but without some environmental support (such as a forum for proposing those ideas), the creativity that a person has within him or her might never be displayed.

Confluence: Concerning the confluence of these six components, creativity is hypothesized to involve more than a simple sum of a person's level on each component. First, there may be thresholds for some components (e.g., knowledge) below which creativity is not possible regardless of the levels on other components. Second, partial compensation may occur in which strength on one component (e.g., motivation) counteracts a weakness on another component (e.g., environment). Third, interactions may occur between components, such as intelligence and motivation, in which high levels on both components could multiplicatively enhance creativity.

4.2.3 Aspects of Creativity

Guilford (1986) considered creative thinking as involving divergent thinking, which emphasises fluency, flexibility, originality, and elaboration. Guilford, however, noted that creative thinking is not the same as divergent thinking, because creativity requires sensitivity to problems as well as redefinition abilities, which include transformations of thought, reinterpretations, and freedom from functional fixedness in driving unique solutions. In order to develop Torrance Tests of Creative Thinking (TTCT) and in its further revisions, Torrance (1966, 1974) has explained six components of creativity. He has described these aspects of creativity in terms of their mode of measurement. These aspects of creativity are:

- 1) *Fluency*: The number of relevant ideas; shows an ability to produce a number of figural images.
- 2) *Flexibility*: Flexibility is the individual's ability to produce not only a large number of responses, ideas or solutions to a problem, but also a variety of responses, ideas or solutions to a problem.
- 3) *Originality*: The number of statistically infrequent ideas; shows an ability to produce uncommon or unique responses.
- 4) *Elaboration*: The number of added ideas; demonstrates the subject's ability to develop and elaborate on ideas.
- 5) *Abstractness of Titles*: The degree beyond labeling; based on the idea that creativity requires an abstraction of thought. It measures the degree a title moves beyond concrete labeling of the pictures drawn.
- 6) *Resistance to Premature Closure*: The degree of psychological openness; based on the belief that creative behaviour requires a person to consider a variety of information when processing information and to keep an "open mind."

Self Assessment Questions

- 1) Define the process of creativity.

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- 2) Describe that how different psychologists differ in understanding creativity.

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- 3) Explain that how Investment and Confluence Theory of approaches creativity.

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- 4) Give an account of aspects of creative thinking.

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4.2.4 Stages of Creativity

The history of research on stages of creativity began with Graham Wallas (1926) who suggested that creative thinking follows four successive steps:

Stage of preparation: The subject begins to gather information about the problem to be solved and attempts some solutions. This stage is characterised by a state of trial-and-error in learning. Therefore, the subject is advised to learn as much as possible about the problem area. In preparation the thinker begins recalling personal experiences and investigating in all different directions to gather information about the problem to be solved. The object of defining the focus question of interest is to list all concepts associated with the focus question. Since the goal from this procedure is to generate the largest possible list, the thinker should not worry about redundancy, relative importance, or relationships at this point.

Stage of incubation: In the second stage the solution exists but is not clear. The subject must not intentionally work on the problem. Instead it is allowed to sink into the unconscious. In this stage the solution exists but is not clear. Therefore, the thinker must not intentionally work on the problem. Instead, he/she should be allowed to sink into the unconscious and the thinker is advised to relax and reflect on his/her focus question which might lead him/her to modification of the focus question.

Stage of illumination: In the third stage the subject suddenly experiences insight into the problem when a new solution, idea, or relationship emerges. In other words, the subject attempts to reformulate his/her ideas or to formulate new ones. The subject is more active and more conscious work is needed in this stage. In the stage of illumination the thinker experiences insight into the problem when a new solution, idea, or relationship emerges. Thus, he/she attempts to reformulate his/her ideas or to formulate new ones.

Stage of verification: Finally, the subject tries and checks the solution. In this stage some modification may also occur to ideas reached in the previous stages. In the stage of verification the thinker tests, tries and checks the solution he/she created. Since this stage is the final one, the thinker may well make some modification to his/her ideas which he/she reached in the previous stages. In this stage thinker should rework the structure of his/her map to represent his/her collective understanding of the interrelationships and connections among groupings, which may include adding, subtracting, or changing super-ordinate concepts, thus, he/she may need to review his/her concept map as he/she gains new knowledge or new insights.

In some situations, the above stages may appear in a different order, or combined into two or three stages. They also do not occur regularly. For example, sometimes the subject's knowledge of the problem area allows him/her to pass over the first stage (preparation) and move on to the next stage (incubation) or even to the third stage.

4.2.5 Creativity and Intelligence

In one extreme opinion, creativity and intelligence are regarded as totally independent of each other. Intelligence is not supposed to influence creativity. Creativity is viewed as a mental operation accessible to everyone. It is supposedly dependent on domain-specific knowledge (i.e. the amount of exposure to and expertise in a given field) and deliberate practice.

This position denies not only the influence of intelligence, but of any individual difference beyond knowledge and motivational factors, on creativity.

A high IQ has proven as insufficient for creativity ever since Terman's (1925) famous longitudinal study of 1528 highly gifted children, which had a mean IQ of 151. While most of these children achieved remarkable occupational success in later life, none of them showed a noteworthy sign of creativity. Most of the studies concerning the association between psychometric intelligence and creativity yielded only a weak relationship. For example, Torrance (1977) reported that the median of 178 correlation coefficients between IQ and the TTCT was only .20. Also, factor analyses of IQ and creativity tests yielded separate factors.

However, a creative person's IQ has been demonstrated to be at least a standard deviation above the mean, often more. Guilford (1967) suggested a hypothesis that a minimal level of IQ, often arbitrary set to 120, should be necessary, but not sufficient for creativity. Creative achievement was thought to be impossible below this threshold. Guilford also proposed that scatter plots of IQ and creativity should show a triangular pattern (which gave Guilford's claim sometimes the name 'triangularity hypothesis') with no data points in the low IQ/high creativity quadrant. This threshold view of creativity is so plausible that it is widely accepted, though empirical test are scarce and more likely to show a disconfirming tendency.

Hayes (1989) proposed an alternative 'certification hypothesis', which doubted intrinsic links between creativity and intelligence. Instead, it stated that most possibilities to display a recognisable level of creativity, like occupations in architecture or science, simply require a high level of formal education. Since academic performance is correlated with IQ, society simply denies creative individuals of low IQ the chance to express their talent adequately.

4.2.6 Measurement of Creativity

Houtz and Krug (1995) provide a review of several tests developed for the assessment of creativity. The review reveals that most of the tests of creativity intend to measure divergent thinking. Within the category of divergent thinking, Houtz and Krug (1995) present the Torrance Test of Creative Thinking (TTCT) (Torrance 1966), The Wallach and Kogan Tests, The Guilford Battery.

The most widely used test on creativity is the *Torrance Test of Creative Thinking* (TTCT). It is also the one that has the most extended research on their reliability and validity (Kim 2006). This test has been translated into more than 30 languages and it is used in different places as a tool to assess creative potential. It is based on Guilford's Structure of the Intellect (SOI) battery that included some measures of divergent thinking. Thus, it measures creativity through divergent thinking.

The TTCT was developed in 1966, and it has been re-normed four times: 1974, 1984, 1990 and 1998. There are two forms, TTCT-Verbal and Figural with two parallel tests (form A and B). Each test is expected to measure

- 1) Fluency: The number of ideas: Total number of relevant responses.
- 2) Originality: The rarity of ideas: Number of statistically infrequent ideas. The score is 0 if the idea is common, and 1 if it is unique.
- 3) Elaboration: The number of added ideas.
- 4) Flexibility: Number of categories of the relevant responses.

In 1990 Torrance deleted the flexibility scale, since it correlated highly with fluency and added two measures of creative potential, viz., (i) abstractness of titles and (ii) resistance to premature closure.

While (i) abstractness of title refers to the degree a title moves beyond concrete labelling of pictures drawn, (ii) resistance to premature closure pertains to measure the degree of psychological openness. The test can be administered in around 30 minutes, but the process of scoring requires some training and specific country norms.

The 1998 manual provides norms for the United States and includes both grade related and age related norms. Thus, there is some country specificity in the measurement of creativity. Kim (2006) reported some normative measures in other countries. These norms have usually been developed for research activities.

Criticisms against TTCT

There are 4 main criticisms against this test and these are:

- 1) The response set might influence the results. Thus, different order in the presentation of the items leads to different results.
- 2) Creativity tests administered under different conditions lead to differences in performance.
- 3) Raters of the TTCT might differ considerably in their scores to a similar person.
- 4) The structure of the test itself is inadequate.

Self Assessment Questions

1) Explain the stages of creativity.

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2) Describe how creativity is related to intelligence.

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3) Explain the threshold hypothesis.

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4) Give an account of measurement of creativity.

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4.3 PROBLEM SOLVING

The thought process involved in a person's effort to remove obstacles in the way to achieve the goal state is called problem solving. Such a process is involved in critical thinking in taking many important decisions of life as well as in solving simple routine problems. Psychological researches have uncovered many aspects of problem solving behaviour which will be discussed in the following sections.

4.3.1 Terms Related to Problem Solving

Original or initial state: Problem solving begins with a certain original state called the initial state of a problem.

Goal or end state: This is what will be reached if the problem is solved. The goal state is what is desired by the person. The goal state has some properties defined by the person.

The person concerned who is with the initial state of the problem and wants to reach the goal, puts in efforts to reach that goal. There may be obstacles to reach the goal which will have to be overcome.

Person / operator: This refers to the person who is in the initial state and strives to achieve the goal or end state through application of certain skills and techniques which would facilitate overcoming the obstacle and reaching the goal state. Operator manipulates the elements involved in the problem internally with the help of some global or personal symbols or visual images.

Problem space: Initial state, goal state and operator combine to form the problem space. The problem space includes a number of elements in it that are required to be organised in a particular manner. A successful understanding of the problem space would require: coherence, correspondence and relationship to background knowledge. Coherent understanding of the problem space refers to connecting the elements in a meaningful manner. A successful understanding also requires a close correspondence between the internal representation and the elements of the problem space. None of the elements should be left unmatched and also none of them should be mismatched. Therefore, proper matched connections should be made among all the elements.

Rules: These refer to rules that exist in converting the problem state into a goal state.

More specifically it may be stated that Problem solving behaviour begins with an obstacle or difference between *original* or *initial state* and *goal* or *end state*. The goal is desired by the person/s or *operator/s* in the situation and has some properties defined by the operator., defined by some *rules*, to convert the problem state into the goal state.

An Example of Problem Solving: A classical example of problem solving behaviour may be explained with the help of Kohler's experiments with a chimpanzee. In one experiment, Kohler (1927) put a hungry chimpanzee (operator) in a closed cage with bananas hanging from the roof (goal state) and three boxes on the floor. It should be noted that the chimpanzee can come closer to the bananas only by putting all the three boxes together in vertical manner (rule). In Kohler's experiment, after a series of irrelevant behaviours the chimpanzee suddenly solved the problem and reached to the bananas. Such sudden solutions of the problem resulted from internal representation and understanding of the problem which was continuously going on in the chimpanzee's unconscious and is termed as insight by Kohler and other *Gestalt* psychologists.

4.3.2 Typologies of Problems

Well-defined and Ill-defined Problems

A problem is well-defined if there is a definable initial state and a goal state, definite number of operators well identified and clear and explicit rules and sub-goals to convert the initial state into the goal state.

The problem faced by the chimpanzee in the Kohler's experiment is a good example of a welldefined problem.

However an ill-defined problem is in which one or all of the elements of the problem space (initial state, goal state, operators and rules) are not clearly defined. Creation of a painting is a unique example of ill-defined problems.

Problems of Inducing Structure:

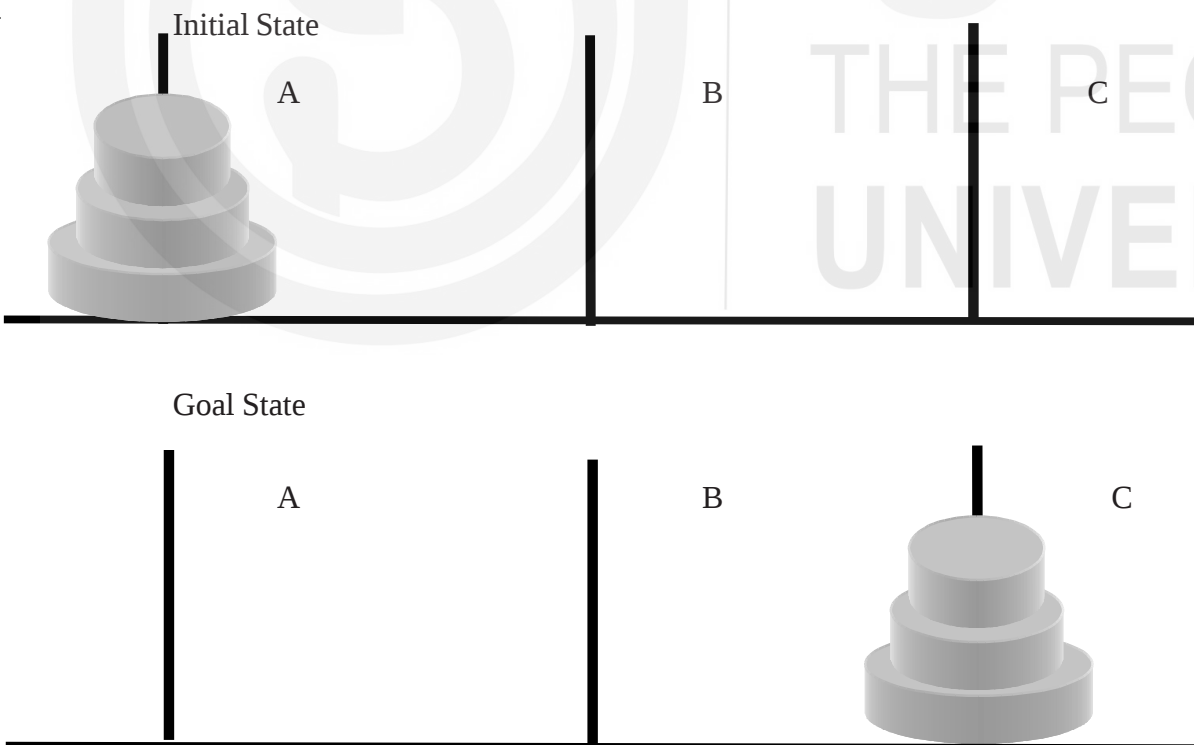
Problems of inducing structure require determining relationship among several elements of the problem. For example take the analogy problem in which the operator is required to find a structure in some elements with clearly defined rules. Example of structured elements are "bird to sky as fish is to water".

Solving analogy problems requires three types of cognitive skills:

- 1) Process of attribute discovery
- 2) Process of encoding
- 3) Process of comparing encoded attributes and evaluating attribute based structure among the elements.

Problems of Transformation

Problems of transformation require finding a sequence of operations to transform the initial state into the goal state. A classic example of such a problem is Tower of Hanoi. A modified version of the problem is illustrated in the figure given below:



At the initial state, there are three discs placed in peg A. Operator is required to move all the three discs on to the peg C. Rules of the game are that only one and the top disc can be moved at a time and the bigger disc cannot be placed over the smaller one.

Problems of Arrangement:

Problems of arrangement requires the operator to rearrange the elements of the problem according to some criterion. In some of such problems the arrangement criterion is predefined, while in others the operator himself is required to discover it. An example of such problems is anagram in which order of letters of a word changed and the operator is asked to rearrange their sequence to form a meaningful word.

The cognitive skill needed to solve an anagram is constructive search by which operator systematically examines reasonable combinations of letters until the meaningful sequence is found.

4.3.3 Stages of Problem Solving

Gestalt psychologists suggest that problem solving behaviour also follows the stages that are followed in creative thinking: preparation, incubation, illumination or insight and verification. These stages have already been discussed in the earlier section.

According to Polya, there are four stages involved in problem solving and these are as given below

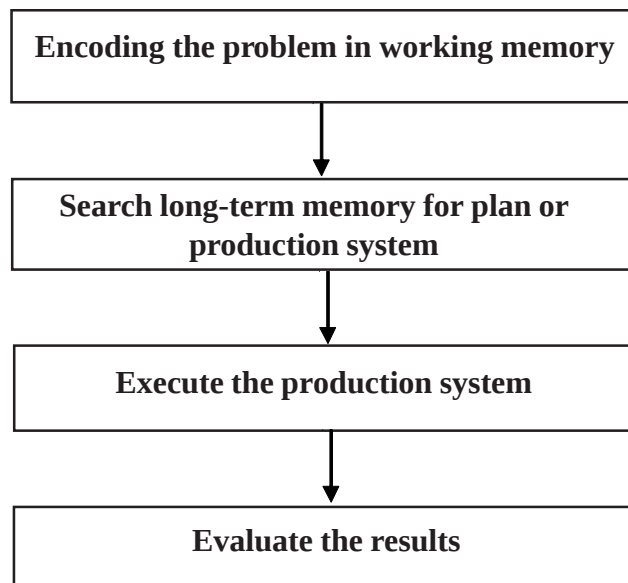
Stage 1: Define, understand and think about the problem. In this stage, there is identification of the actual problem, attributes of the problem, area of knowledge involved in solving the problem and collecting relevant information.

Stage 2: Devise a plan for solution. This stage includes thinking of alternate ways to solve the problem and preparing a flowchart of solution.

Stage 3: Carry out the plan. This stage of problem solving is to execute the solution of the problem.

Stage 4: Looking back. This involves verifying that the problem solved was the one originally defined, and also checking reasonableness, criteria and constraints as well as communicate results.

An information processing translation of the Polya's stages has also been described which is presented in the following model: (See figure below)



4.3.4 Strategies of Problem Solving

Even if the operator has all the basic knowledge and background skills, yet there is no guarantee that they will solve the problem successfully.

In order to be successful in solving a problem, an additional element needed is to have a general strategy that can be used for problem solving.

A strategy is a set of sequential steps (or procedure) used by a problem solver in arriving at a solution. The strategy should help the operator by guiding him/her to efficiently extract relevant data from the problem space and by giving a planned approach to solving the problem. Cognitive psychologists have described two major types of strategies generally used by an operator and these are termed as algorithms and heuristics. Let us see what these are:

4.3.4.1 Algorithms

An algorithm is a strategy that ensures the correct solution of the problem, if the well-defined rule of the solution is properly followed. In an anagram problem, an algorithm would be attempting all the possible letter sequences until the correct and meaningful word is found. There are four essential properties of an algorithm:

- 1) Each step of an algorithm must be exact. An algorithm must be precisely and unambiguously described, so that there remains no uncertainty.
- 2) An algorithm must terminate. The ultimate purpose of an algorithm is to solve a problem. If the process does not stop when executed, one will not be able to get any result from it. Therefore, an algorithm must contain a finite number of steps in its execution.
- 3) An algorithm must be effective. It must provide the correct answer to the problem.
- 4) An algorithm must be general. This means that it must solve every instance of the problem. For example, a program that computes the area of a rectangle should work on all possible dimensions of the rectangle, within the limits of the programming language and the machine.

Although algorithm is a guarantee to reach to the solution, the effort and time involved in using it is so great that a human operator rarely uses this strategy.

4.3.4.2 Heuristics

Heuristics are general suggestions or “rules of thumb” that are useful in solving a variety of problems. Heuristics are powerful and general. They do not ensure a correct solution to the problem. That is why there are so many of them and if one does not work, another may be tried upon. General heuristics are usually context free and apply across many different situations. Specific heuristics are used in specialised areas, like applying the conservation of momentum principle to solve collision problems in physics, or telling students to check the units, neglect small terms, or use crude approximations.

Means-end analysis

Probably the most common and general heuristic is the ‘means-end analysis’. Simply stated, this heuristic says to do something to get a little closer to the goal. This heuristic helps break down a problem into pieces. For example, the ultimate

goal is taken in short term goals and each of these short term goals will have to be achieved and doing so helps the person to get closer to the goal and ultimately reach it.

If a large problem is broken down into pieces, it is important to self monitor the sub goals, that is whether the person has achieved it or not. This self-monitoring is known as meta-cognition. Meta-cognition is essential for any extended activity, especially problem solving, because the problem solver needs to be aware of the current activity, of the overall goal, the strategies used to attain the goal and the effectiveness of those strategies.

Working backward

This strategy starts with the goal state and the operator moves backward toward the initial state. This strategy is found to be very useful in solving problems like paper-pencil maze. Sometimes the problem solver uses this method by combining it with the means end analysis. However, working backward is useful only when the end state is uniquely well defined with an unclear initial state.

Analogies

Heuristic of analogy uses experiences of strategies used to solve past problems in solving a current problem. This strategy relies on discovering common attributes among various problems solved at previous occasions and the problem being faced presently.

4.3.5 Factors Affecting Problem Solving

Effectiveness of a problem solving behaviour is measured on two criteria: time taken in solving the problem and probability of getting the solution. An effective solution of a problem is dependent upon a number of factors. Some of these factors are inherent in the problem itself, while others belong to the personal characteristics of the problem solver. These include (i) Nature of the problem (ii) Degree of difference between the initial and the goal state (iii) The perceiver's set (iv) functional fixedness. These are being discussed below:

i) Nature of the problem

What is the magnitude of the problem, the difficulty level of the problem etc. are part of nature of the problem. Also if the initial state of the problem is too different from that of the final goal of the problem the difficulty level increases and solving the problem becomes somewhat difficult. While size of a problem is positively related with the number of elements present in the problem space, it is observed that as the size of the problem increases, it becomes all the more difficult to reach solution to the problem and also it becomes more time consuming. An example is the typical anagram problems, where an increase in the number of letters of the anagrams enhances the difficulty level of the problem.

ii) Greater the difference between initial and goal states decreases the likelihood of solution. In such situations problem space is more disorganised and therefore, the operator is required to take more steps to reach to the solution. To give an example, take a complete jumble of letters in an anagram which clearly describes such a situation.

If the problem is a general one which is frequently encountered, the problem solver becomes familiar with the steps to be followed to reach the solution and therefore, the problem becomes less difficult.

- iii) The perceiver's Set is defined as a tendency to perceive and respond to a particular stimulus in a stereotypical manner. Set is formed in a situation where a person successively and systematically perceives and responds to a stimulus in a similar way. Set may prove to have facilitatory, as well as inhibitory impact on problem solving.

If the past experience paved the way to the formation of certain mental set, then the solution will become easier. But in case of greater difference among the experiences, the mental set would hinder finding solution to the problem. An example of the effect of set may be observed by pronouncing the following words:

MACDONALD MACMOHAN MACGREGOR MACHINERY

If you pronounced the last word as MacHinery, the effect of set worked on you. However, the effect of set can be minimized by increasing time interval between practice and trial, by explicit instruction to not follow the previously learned rules and by introducing some exceptions in the practice.

- iv) Functional fixedness: Generally we categorise objects on the basis of their use in our daily life. Whenever we think of those objects their functional features dominate our thought process. Functional fixedness refers to the tendency to perceive the objects with their customary and stereotypical use.

In a broader sense, functional fixedness is also an example of mental set, which hinders the probability to achieve solution.

Self Assessment Questions

- 1) Define the problem solving behaviour.

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- 2) Describe the terms related to problem solving.

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3) Explain the various types of problems.

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4) Give an account of the strategies used in problem solving.

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5) Describe the factors affecting problem solving.

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4.4 LET US SUM UP

Creativity is defined as a goal directed thinking which is unusual, novel and useful. Such a thought process rejects the previously accepted ideas and organises the unclear situation in new and coherent way. Investment theory states that creativity requires a confluence of six distinct but interrelated resources: intellectual abilities, knowledge, styles of thinking, personality, motivation, and environment. Divergent thinking is thought to be a central component in any type of creative thinking. Other aspects of creative thinking are: fluency, flexibility, originality, elaboration, abstraction and resistance to premature closure. Creativity follows a four step process consisting of preparation, incubation, illumination and verification. Although creativity requires a minimum IQ of 120, but beyond that level relationship between intelligence and creativity is either not clear or is very weak. Most of the tests of creativity intend to measure divergent thinking. Such a widely used test is TTCT which includes both verbal and figural items.

Problem solving is another kind of directed thinking that begins with an obstacle or a difference between initial state and the goal state. The person is required to reorganise the problem situation to remove the obstacle and convert the problem state into then goal state. A successful understanding of problem space requires coherence, correspondence and relationship to background knowledge. Types of

problems referred in the psychological researches are well-defined and ill-defined problems, problems of inducing structure, transformation and arrangement. Cognitive psychologists have described two major types of strategies used in problem solving: algorithms and heuristics. The factors affecting the success of problem solving behaviour include the size of the problem, difference between problem state and goal state, generality of the problem and set and functional fixedness of the problem solver.

4.5 UNIT END QUESTIONS

- 1) Define the process of creativity and describe that how different psychologists differ in understanding creativity.
- 2) Explain that how Investment and Confluence Theory of approaches creativity and present an account of aspects of creative thinking.
- 3) Briefly discuss the stages of creativity.
- 4) Describe that how creativity is related with intelligence and explain the threshold hypothesis in this regard.
- 5) Give an account of measurement of creativity.
- 6) Define the problem solving behaviour and describe the terms related to problem solving.
- 7) Explain the various types of problems and present an account of the strategies used in problem solving.
- 8) Describe the factors affecting problem solving.

4.6 GLOSSARY

Creativity	: Creativity is a goal directed thinking which is unusual, novel and useful.
Historical creativity	: Historical creativity is a creative thinking that becomes so important that it influence the whole human civilisation.
Investment theory	: Investment theory states that creativity requires a confluence of six distinct but interrelated resources: intellectual abilities, knowledge, styles of thinking, personality, motivation, and environment.
Threshold hypothesis	: The hypothesis that state that a minimal level of IQ, often arbitrary set to 120 should be necessary, but not sufficient for creativity.
Problem solving	: The directed thought process involved in a person's effort to remove obstacles in the way to achieve the goal state is called problem solving.
Well-defined and ill-defined problems	: A problem is well-defined if there is a definable initial state and a goal state, the number of operators is definite and they all are well identified and there are quite explicit rules and

sub-goals to convert the initial state into the goal state. On the contrary, in case of ill-defined problem one or all of the elements of the problem space (initial state, goal state, operators and rules) are not clearly defined.

Problems of inducing structure	:	Problems of inducing structure require determining relationship among several elements of the problem.
Problems of transformation	:	Problems of transformation require finding a sequence of operations to transform the initial state into the goal state.
Problems of arrangement	:	Problems of arrangement requires the operator to rearrange the elements of the problem according to some criterion.
Strategy of problem solving	:	A strategy is a set of sequential steps (or procedure) used by a problem solver in arriving at a solution.
Algorithm	:	An algorithm is a strategy that ensures the correct solution of the problem, if the well-defined rule of the solution is properly followed.
Heuristics	:	Heuristics are general suggestions or “rules of thumb” that are useful in solving a great variety of problems but do not ensure a correct solution to the problem.
Set	:	Set is defined as a tendency to perceive and respond to a particular stimulus in a stereotypical manner.
Functional fixedness	:	Functional fixedness refers to the tendency to perceive the objects with their customary and stereotypical use.

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UNIT 1 LANGUAGE ACQUISITION

Structure

- 1.0 Introduction
- 1.1 Objectives
- 1.2 Language and Cognition
- 1.3 Linguistics
 - 1.3.1 The Structure of Language
 - 1.3.2 The Buildings Blocks of Language
- 1.4 Language Acquisition
 - 1.4.1 Stages of Language Acquisition
 - 1.4.2 Language Acquisition and Cognitive Science
 - 1.4.3 Language and Thought
- 1.5 Theories of Language Acquisition
 - 1.5.1 Behaviouristic Theory
 - 1.5.2 Limitations of Behaviourism Theory
 - 1.5.3 Innateness Theory
 - 1.5.4 Evidence to Support Innateness Theory
 - 1.5.5 Limitations of Chomsky's Theory
 - 1.5.6 Cognitive Theory
 - 1.5.7 Limitations of Cognitive Theories
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 - 1.5.9 Limitations of Inputs Theories
- 1.6 The Biology of Language Acquisition
 - 1.6.1 Maturational Changes in Brain
 - 1.6.2 Dissociations Between Language and General Intelligence
 - 1.6.3 Neural Networks
- 1.7 Let Us Sum Up
- 1.8 Unit End Questions
- 1.9 Suggested Readings and References.

1.0 INTRODUCTION

People talk or use language incessantly. Language, to cognitive psychologists, is a system of communication in which thoughts are transmitted by means of sounds (as in speech and music) or symbols (as in written words and gestures). As you read this text, you are engaging in one of the mind's most enchanting processes – the way one mind influences another through language. In this process, some cell assemblies in your brain are permanently changed, new thoughts are made, and, in a very real sense, you are changed.

Cognitive psychology concerns both language and thought and has been popular only since the 1950s. Before that, many psychologists believed that the scientific method could not be applied towards the study of a process as private as thinking. From ancient Greek times, only philosophers and metaphysicians studied the nature of language and thought. The metaphysician René Descartes, for example, famously argued, "I think, therefore I am."

Today, thanks to increasingly sophisticated tools for studying brain activity, cognitive psychology is a thriving science. Cognitive psychologists explore such questions as how language affects thought, whether it is possible to create a “thinking” machine, and why humans are motivated to create art.

1.1 OBJECTIVES

After reading this unit, you will be able to:

- Define and elucidate the concept of language;
- Describe language and cognition;
- Explain theories of language acquisition and their limitations; and
- Explain biology of language acquisition.

1.2 LANGUAGE AND COGNITION

The study of human language is important to cognitive psychologists for the following reasons:

- Human language development represents a unique kind of abstraction, which is basic to cognition. Although other forms of life (bees, birds, dolphins, dogs and so on) have elaborate means of communicating and apes seem to use a form of language abstraction, the degree of abstraction is much greater among humans.
- Language processing is an important component of information processing and storage.
- Human thinking and problem solving can be conceptualised as processes involving language. Many, if not most, forms of thinking and problem solving are internal, that is, done in the absence of external stimuli. Abstraction of puzzles, for example, into verbal symbols provides a way to think about a solution.
- Language is the main means of human communication, the way in which most information is exchanged.
- Language influences perception, a fundamental aspect of cognition. Some argue that how we perceive the world is affected by the language we use to describe it. On the other hand, language development is at least largely based on our perception of language. So the perceptual-language process is one of interdependency; both significantly influence the other. Language from this point of view operates as a window.

The processing of words, speech, and semantics seem to engage specific cerebral areas and thus provide a meaningful link between neuro anatomical structures and language. In addition, the study of pathology of the brain has frequently shown manifest change in language functions, as in the case of aphasia.

1.3 LINGUISTICS

The study of linguistics is the formal description of the structure of language, including a description of speech sounds, meanings, and grammar. Language as

studied by linguists tends to be competency based (dealing with some ideal potential of the speaker-listener), while psychologists generally view language in terms of performance, or how humans use language. The discipline that incorporates both approaches to the study of language is called psycholinguistics.

1.3.1 The Structure of Language

Language is a system of symbols and rules that is used for meaningful communication. A system of communication has to meet *certain criteria* in order to be considered a language:

A language uses symbols, which are sounds, gestures, or written characters that represent objects, actions, events, and ideas. Symbols enable people to refer to objects that are in another place or events that occurred at a different time.

A language is meaningful and therefore can be understood by other users of that language.

A language is generative, which means that the symbols of a language can be combined to produce an infinite number of messages.

A language has rules that govern how symbols can be arranged. These rules allow people to understand messages in that language even if they have never encountered those messages before.

1.3.2 The Building Blocks of Language

Language is organised hierarchically, from phonemes to morphemes to phrases and sentences that communicate meaning

Phonemes are the smallest distinguishable units in a language. In the English language, many consonants, such as *t*, *p*, and *m*, correspond to single phonemes, while other consonants, such as *c* and *g*, can correspond to more than one phoneme. Vowels typically correspond to more than one phoneme. For example, *o* corresponds to different phonemes depending on whether it is pronounced as in *bone* or *woman*. Some phonemes correspond to combinations of consonants, such as *ch*, *sh*, and *th*.

Morphemes are the smallest meaningful units in a language. In the English language, only a few single letters, such as *I* and *a*, are morphemes. Morphemes are usually whole words or meaningful parts of words, such as prefixes, suffixes, and word stems.

Example: The word “disliked” has three morphemes: “dis,” “lik,” and “ed.”

Syntax is a system of rules that governs how words can be meaningfully arranged to form phrases and sentences.

Example: One rule of syntax is that an article such as “the” must come before a noun, not after: “Read the book,” not “Read book the.”

1.4 LANGUAGE ACQUISITION

Language acquisition is one of the central topics in cognitive science. Every theory of cognition has tried to explain it; probably no other topic has aroused such controversy. Possessing a language is the quintessentially human trait: all

normal humans speak, no nonhuman animal does. Language is the main vehicle by which we know about other people's thoughts, and the two must be intimately related. Every time we speak we are revealing something about language, so the facts of language structure are easy to come by; these data hint at a system of extraordinary complexity. Nonetheless, learning a first language is something every child does successfully, in a matter of a few years and without the need for formal lessons. With language so close to the core of what it means to be human, it is not surprising that children's acquisition of language has received so much attention. Anyone with strong views about the human mind would like to show that children's first few steps are steps in the right direction.

In the past, debates about the acquisition of language centered on the same theme as debates about the acquisition of any ability – the nature versus nurture theme. However, current thinking about the language acquisition has incorporated the understanding that acquiring language really involves a natural endowment modified by environment (Bates and Goodman, 1999; Dehaene-Lambertz, Hertz-Painter & Dubois, 2006; Lightfoot, 2003; Maratos, 2003). For example, the social environment, in which infants use their social capacities to interact with others, provides one source of information for language acquisition (Snow, 1999; Tomasello, 1999). Thus the approach to studying language acquisition now revolves around discovering what abilities are innate and how the child's environment tempers these abilities. This process is aptly termed innately guided learning (see Elman & associates, 1996; Jusczyk, 1997).

Before examining the various theories of language acquisition, let's take a look at a series of stages that seem to be universal in language acquisition.

1.4.1 Stages of Language Acquisition

Around the world, people seem to acquire their primary language in pretty much the same sequence and in just about the same way. Research on speech perception finds the same overall pattern of progression. They develop from more general to more specific abilities. That is, as infants we are initially able to distinguish among all possible phonetic contrasts. But over time we lose the ability to distinguish nonnative contrasts in favor of those used in our native language environment (see Jusczyk, 1997). Infants have remarkably acute language-learning abilities. They show these abilities even from an early age (Marcus et al., 1999; Pinker, 1997, 1999).

Within the first few years of life, we humans seem to progress through the following stages in producing language:

Cooing, which comprises of vowel sounds mostly. Cooing is the infant's oral expression that explores the production of vowel sounds. The cooing of infants around the world, including deaf infants, is indistinguishable across babies and languages. Infants are actually better than adults at being able to discriminate sounds that carry no meaning for them (Werker, 1989). They can make phonetic distinctions that adults have lost. During the cooing stage, hearing infants also can discriminate among all phones, not just phonemes characteristic of their own language.

Babbling, which comprises consonant as well as vowel sounds; to most people's ears, the babbling of infants growing up among speakers from different language

groups sounds very similar (Oller & Eilers, 1998). At the babbling stage, deaf infants no longer vocalise. The sounds produced by hearing infants change. Babbling is the infant's preferential production largely of those distinct phonemes—both vowels and consonants—that are characteristic of the infant's own language (Locke, 1994).

One-word utterances; these utterances are limited in both the vowels and the consonants they utilise (Ingram, 1999). Eventually, the infant utters his or her first word. It is followed shortly by one or two more. Soon after, yet a few more follow. The infant uses these one word utterances — termed holophrases — to convey intentions, desires, and demands. Usually the words are nouns describing familiar objects that the child observes (example; car, book, ball, baby, toy, nose) or wants (e.g. mama, dada, milk, cookie). By 18 months of age, children typically have vocabulary of 3 to 100 words (Seigler, 1986). The young child's vocabulary cannot yet encompass all that the child wishes to describe. As a result, the child commits overextension error. An *overextension error* is erroneously extending the meaning of words in the existing lexicon to cover things and ideas for which a new word is lacking. For example, the general term for any four legged animal may be 'doggie'.

Two-word utterances and telegraphic speech. Gradually, between 1.5 to 2.5 years of age, children start combining single words to produce two-word utterances. Thus begin an understanding of syntax. These early syntactical communications seem more like telegrams than conversation. The articles, prepositions, and other functional morphemes are usually left out. Hence, linguists refer to these early utterances with rudimentary syntax as *telegraphic speech*. e.g. "want juice", "doggie bite", "mommy sit". These simple pairings of words convey a wealth of information about a child's intentions and needs.

Basic adult sentence structure (present by about age 4 years), with continuing vocabulary acquisition. Vocabulary expands rapidly. It more than triples from 300 words at about 2 years of age to about 1000 words at 3 years of age. Almost incredible, by age of 4, children acquire the foundations of adult syntax and language structure. By age of 5 years, most children also can understand and produce quite complex and uncommon sentence constructions. By age of 10 years, children's language is fundamentally the same as that of adults.

Normal children can differ by a year or more in their rate of language development, though the stages they pass through are generally the same regardless of how stretched out or compressed.

1.4.2 Language Acquisition and Cognitive Science

Language acquisition is not only inherently interesting; studying it is one way to look for concrete answers to questions that permeate cognitive science. The scientific study of language acquisition began around the same time as the birth of cognitive science, in the late 1950's. The historical catalyst was Noam Chomsky's review of Skinner's Verbal Behaviour (Chomsky, 1959). At that time, Anglo-American natural science, social science, and philosophy had come to a virtual consensus about the answers to the questions listed above. The mind consisted of sensorimotor abilities plus a few simple laws of learning governing gradual changes in an organism's behavioural repertoire. Therefore language

must be learned, it cannot be a module, and thinking must be a form of verbal behaviour, since verbal behaviour is the prime manifestation of “thought” that can be observed externally.

Chomsky argued that language acquisition falsified these beliefs in a single stroke: children learn languages that are governed by highly subtle and abstract principles, and they do so without explicit instruction or any other environmental clues to the nature of such principles. Hence language acquisition depends on an innate, species-specific module that is distinct from general intelligence. Much of the debate in language acquisition has attempted to test this once-revolutionary, and still controversial, collection of ideas. The implications extend to the rest of human cognition.

1.4.3 Language and Thought

Is language simply grafted on top of cognition as a way of sticking communicable labels onto thoughts (Fodor, 1975; Piaget, 1926)? Or does learning a language somehow mean learning to think in that language? A famous hypothesis, outlined by Benjamin Whorf (1956), asserts that the categories and relations that we use to understand the world come from our particular language, so that speakers of different languages conceptualise the world in different ways.

Language acquisition, then, would be learning to think, not just learning to talk. This is an intriguing hypothesis, but virtually all modern cognitive scientists believe it is false (see Pinker, 1994a). Babies can think before they can talk.

Cognitive psychology has shown that people think not just in words but in images and abstract logical propositions. Language acquisition has a unique contribution to make to this issue. As we shall see, it is virtually impossible to show how children could learn a language unless you assume they have a considerable amount of nonlinguistic cognitive machinery in place before they start.

1.5 THEORIES OF LANGUAGE ACQUISITION

How do we explain children’s course of language acquisition — most importantly, their inevitable and early mastery? Several kinds of mechanisms are at work. As we will see in the next section, the brain changes after birth, and these maturational changes may govern the onset, rate, and adult decline of language acquisition capacity. General changes in the child’s information processing abilities (attention, memory, short-term buffers for acoustic input and articulator output) could leave their mark as well. Language acquisition is so complex that one needs a precise framework for understanding what it involves.

Over the last fifty years, several theories have been put forward to explain the process by which children learn to understand and speak a language. They can be summarised as follows: (Refer to table below)

Table 1.1: Theory and the central idea associated with author

Theory	Central Idea	Individual most often associated with theory
Behaviourist	Children imitate adults. Their correct utterances are reinforced when they get what they want or are praised	Skinner
Innateness	A child's brain contains special language learning mechanisms at birth	Chomsky
Cognitive	Language is just one aspect of a child's overall intellectual development.	Piaget
Interaction	This theory emphasises the interaction between children and their care givers.	Bruner

We shall consider each of these in turn. Before we do, it is important to recognise that they should not be seen simply as conflicting theories, replacing each other in a sequence. Although Behaviourism is now seen as offering only a very limited explanation, each theory has added to our overall understanding, placing emphasis on different aspects of the process.

1.5.1 Behaviouristic Theory

The behaviourist psychologists developed their theories while carrying out a series of experiments on animals. They observed that rats or birds, for example, could be taught to perform various tasks by encouraging habit-forming. Researchers rewarded desirable behaviour. This was known as positive reinforcement. Undesirable behaviour was punished or simply not rewarded — negative reinforcement. The behaviourist B. F. Skinner then proposed this theory as an explanation for language acquisition in humans. In *Verbal Behaviour* (1957), he stated: “The basic processes and relations which give verbal behaviour its special characteristics are now fairly well understood. Much of the experimental work responsible for this advance has been carried out on other species, but the results have proved to be surprisingly free of species restrictions. Recent work has shown that the methods can be extended to human behaviour without serious modifications.” (cited in Lowe and Graham, 1998, p.68)

Skinner suggested that a child imitates the language of its parents or carers. Successful attempts are rewarded because an adult who recognises a word spoken by a child will praise the child and/or give it what it is asking for. The linguistic input was key — a model for imitation to be either negatively or positively reinforced. Successful utterances are therefore reinforced while unsuccessful ones are forgotten. No essential difference between the way a rat learns to negotiate a maze and a child learns to speak.

1.5.2 Limitations of Behaviourism Theory

While there must be some truth in Skinner's explanation, there are many objections to it.

Language is based on a set of structures or rules, which could not be worked out simply by imitating individual utterances. The mistakes made by children reveal

that they are not simply imitating but actively working out and applying rules. For example, a child who says “drinked” instead of “drank” is not copying an adult but rather over-applying a rule.

The vast majority of children go through the same stages of language acquisition. Apart from certain extreme cases, the sequence seems to be largely unaffected by the treatment the child receives or the type of society in which s/he grows up.

Children are often unable to repeat what an adult says, especially if the adult utterance contains a structure the child has not yet started to use.

Few children receive much explicit grammatical correction. Parents are more interested in politeness and truthfulness. According to Brown, Cazden & Bellugi (1969): “It seems to be truth value rather than well-formed syntax that chiefly governs explicit verbal reinforcement by parents — which renders mildly paradoxical the fact that the usual product of such a training schedule is an adult whose speech is highly grammatical but not notably truthful.” (cited in Lowe and Graham, 1998)

There is evidence for a critical period for language acquisition. Children who have not acquired language by the age of about seven will never entirely catch up. The most famous example is that of Genie, discovered in 1970 at the age of 13. She had been severely neglected, brought up in isolation and deprived of normal human contact. Of course, she was disturbed and underdeveloped in many ways. During subsequent attempts at rehabilitation, her caretakers tried to teach her to speak. Despite some success, mainly in learning vocabulary, she never became a fluent speaker, failing to acquire the grammatical competence of the average five-year-old.

1.5.3 Innateness Theory

Noam Chomsky published a criticism of the behaviourist theory in 1957. In addition to some of the arguments listed above, he focused particularly on the impoverished language input children receive. This theory is connected with the writings of Chomsky, although the theory has been around for hundreds of years. Children are born with an innate capacity for learning human language. Humans are destined to speak. Children discover the grammar of their language based on their own inborn grammar. Certain aspects of language structure seem to be preordained by the cognitive structure of the human mind. This accounts for certain very basic universal features of language structure: every language has nouns/verbs, consonants and vowels. It is assumed that children are pre-programmed, hard-wired, to acquire such things.

Yet no one has been able to explain how quickly and perfectly all children acquire their native language. Every language is extremely complex, full of subtle distinctions that speakers are not even aware of. Nevertheless, children master their native language in 5 or 6 years regardless of their other talents and general intellectual ability. Acquisition must certainly be more than mere imitation; it also doesn't seem to depend on levels of general intelligence, since even a severely retarded child will acquire a native language without special training. Some innate feature of the mind must be responsible for the universally rapid and natural acquisition of language by any young child exposed to speech.

Chomsky concluded that children must have an inborn faculty for language acquisition. According to this theory, the process is biologically determined - the human species has evolved a brain whose neural circuits contain linguistic information at birth. The child's natural predisposition to learn language is triggered by hearing speech and the child's brain is able to interpret what s/he hears according to the underlying principles or structures it already contains. This natural faculty has become known as the Language Acquisition Device (LAD).

Chomsky did not suggest that an English child is born knowing anything specific about English, of course. He stated that all human languages share common principles. (For example, they all have words for things and actions — nouns and verbs.) It is the child's task to establish how the specific language s/he hears expresses these underlying principles.

For example, the LAD already contains the concept of verb tense. By listening to such forms as “worked”, “played” and “patted”, the child will form the hypothesis that the past tense of verbs is formed by adding the sound /d/, /t/ or /id/ to the base form. This, in turn, will lead to the “virtuous errors” mentioned above. It hardly needs saying that the process is unconscious. Chomsky does not envisage the small child lying in its cot working out grammatical rules consciously!

Chomsky's ground-breaking theory remains at the centre of the debate about language acquisition. However, it has been modified, both by Chomsky himself and by others. Chomsky's original position was that the LAD contained specific knowledge about language. Dan Isaac Slobin has proposed that it may be more like a mechanism for working out the rules of language:

“It seems to me that the child is born not with a set of linguistic categories but with some sort of process mechanism — a set of procedures and inference rules, if you will - that he uses to process linguistic data. These mechanisms are such that, applying them to the input data, the child ends up with something which is a member of the class of human languages. The linguistic universals, then, are the *result* of an innate cognitive competence rather than the content of such a competence” (cited in Russell, 2001).

1.5.4 Evidence to Support Innateness Theory

Work in several areas of language study has provided support for the idea of an innate language faculty. Three types of evidence are offered here:

- 1) Slobin has pointed out that human anatomy is peculiarly adapted to the production of speech. Unlike our nearest relatives, the great apes, we have evolved a vocal tract which allows the precise articulation of a wide repertoire of vocal sounds.
- 2) Neuro-science has also identified specific areas of the brain with distinctly linguistic functions, notably Broca's area and Wernicke's area. Stroke victims provide valuable data: depending on the site of brain damage, they may suffer a range of language dysfunction, from problems with finding words to an inability to interpret syntax.
- 3) Experiments aimed at teaching chimpanzees to communicate using plastic symbols or manual gestures have proved controversial. It seems likely that

our ape cousins, while able to learn individual “words”, have little or no grammatical competence. Pinker (1994) offers a good account of this research.

The formation of creole varieties of English appears to be the result of the LAD at work. The linguist Derek Bickerton has studied the formation of Dutch-based creoles in Surinam. Escaped slaves, living together but originally from different language groups, were forced to communicate in their very limited Dutch.

The result was the restricted form of language known as a pidgin. The adult speakers were past the critical age at which they could learn a new language fluently — they had learned Dutch as a foreign language and under unfavourable conditions. Remarkably, the children of these slaves turned the pidgin into a full language, known by linguists as a creole. They were presumably unaware of the process but the outcome was a language variety which follows its own consistent rules and has a full expressive range. Creoles based on English are also found, in the Caribbean and elsewhere.

Studies of the sign languages used by the deaf have shown that, far from being crude gestures replacing spoken words, these are complex, fully grammatical languages in their own right. A sign language may exist in several dialects. Children learning to sign as a first language pass through similar stages to hearing children learning spoken language. Deprived of speech, the urge to communicate is realised through a manual system which fulfils the same function. There is even a signing creole, again developed by children, in Nicaragua (Pinker, 1994).

1.5.5 Limitations of Chomsky's Theory

Chomsky's work on language was theoretical. He was interested in grammar and much of his work consists of complex explanations of grammatical rules. He did not study real children. The theory relies on children being exposed to language but takes no account of the interaction between children and their caretakers. Nor does it recognise the reasons why a child might want to speak, the functions of language.

In 1977, Bard and Sachs published a study of a child known as Jim, the hearing son of deaf parents. Jim's parents wanted their son to learn speech rather than the sign language they used between themselves. He watched a lot of television and listened to the radio, therefore receiving frequent language input. However, his progress was limited until a speech therapist was enlisted to work with him. Simply being exposed to language was not enough. Without the associated interaction, it meant little to him.

Subsequent theories have placed greater emphasis on the ways in which real children develop language to fulfil their needs and interact with their environment, including other people.

1.5.6 Cognitive Theory

The Swiss psychologist Jean Piaget (1896-1980) placed acquisition of language within the context of a child's cognitive development. He argued that a child has to understand a concept before s/he can acquire the particular language form which expresses that concept. Cognitive theory views language acquisition within the context of the child's broader intellectual development. Since the cognitive

theory of language acquisition is based on Piaget's theory of cognitive development, a brief description and understanding of this theory is must.

Piaget suggested that children go through four separate stages in a fixed order that is universal in all children. Piaget declared that these stages differ not only in the quantity of information acquired at each, but also in the quality of knowledge and understanding at that stage. He suggested that movement from one stage to the next occurred when the child reached an appropriate level of maturation and was exposed to relevant types of experiences. Without experience, children were assumed incapable of reaching their highest cognitive ability. Piaget's four stages are known as the sensorimotor, preoperational, concrete operational, and formal operational stages.

The *sensory motor* stage in a child is from birth to approximately two years. During this stage, a child has relatively little competence in representing the environment using images, language, or symbols. An infant has no awareness of objects or people that are not immediately present at a given moment. Piaget called this a lack of object permanence. Object permanence is the awareness that objects and people continue to exist even if they are out of sight. In infants, when a person hides, the infant has no knowledge that they are just out of sight. According to Piaget, this person or object that has disappeared is gone forever to the infant.

The *preoperational* stage is from the age of two to seven years. The most important development at this time is language. Children develop an internal representation of the world that allows them to describe people, events, and feelings. Children at this time use symbols, they can pretend when driving their toy car across the couch that the couch is actually a bridge. Although the thinking of the child is more advanced than when it was in the sensory motor stage, it is still qualitatively inferior to that of an adult. Children in the preoperational stage are characterised by what Piaget called egocentric thoughts. The world at this stage is viewed entirely from the child's own perspective. Thus a child's explanation to an adult can be uninformative.

Three-year-olds will generally hide their face when they are in trouble—even though they are in plain view, three-year-olds believe that their inability to see others also results in others' inability to see them. A child in the preoperational stage also lacks the principle of conservation. This is the knowledge that quantity is unrelated to the arrangement and physical appearance of objects. Children who have not passed this stage do not know that the amount, volume or length of an object does not change length when the shape of the configuration is changed. If you put two identical pieces of clay in front of a child, one rolled up in the shape of a ball, the other rolled into a snake, a child at this stage may say the snake piece is bigger because it is rolled out. Piaget declared that this is not mastered until the next stage of development.

The *concrete operational* stage lasts from the age of seven to twelve years of age. The beginning of this stage is marked by the mastery of the principal of conservation. Children develop the ability to think in a more logical manner and they begin to overcome some of the egocentric characteristics of the preoperational period. One of the major ideas learned in this stage is the idea of reversibility. This is the idea that some changes can be undone by reversing an earlier action.

An example is the ball of clay that is rolled out into a snake piece of clay. Children at this stage understand that you can regain the ball of clay formation by rolling the piece of clay the other way. Children can even conceptualise the stage in their heads without having to see the action performed. Children in the concrete operational stage have a better understanding of time and space. Children at this stage have limits to their abstract thinking, according to Piaget.

The *formal operational* stage begins in most people at age twelve and continues into adulthood. This stage produces a new kind of thinking that is abstract, formal, and logical. Thinking is no longer tied to events that can be observed. A child at this stage can think hypothetically and use logic to solve problems. It is thought that not all individuals reach this level of thinking. Most studies show only forty to sixty percent of American college students and adults fully achieve it.

Piaget's suggestion, that cognitive performance cannot be attained unless cognitive readiness is brought about by maturation and environmental stimuli, has been instrumental in determining the structure of educational curricula.

Cognitive theory of language acquisition suggests that a child first becomes aware of a concept, such as relative size, and only afterward do they acquire the words and patterns to convey that concept. Simple ideas are expressed earlier than more complex ones even if they are grammatically more complicated—Conditional mood is one of the last. Conceptual development might affect language development: if a child has not yet mastered a difficult semantic distinction, he or she may be unable to master the syntax of the construction dedicated to expressing it.

The complexity of a grammatical form has a demonstrable role in development: simpler rules and forms appear in speech before more complex ones, all other things being equal. For example, the plural marker -s in English (e.g. cats), which requires knowing only whether the number of referents is singular or plural, is used consistently before the present tense marker -s (he walks), which requires knowing whether the subject is singular or plural and whether it is a first, second, or third person and whether the event is in the present tense (Brown, 1973).

There is a consistent order of mastery of the most common function morphemes in a language. Here's an example from English: first—-ing, then *in* and *on*, then the plural -s, last are the forms of the verb *to be*. Seems to be conditioned by logical complexity: plural is simple, while forms of the verb *to be* require sensitivity to both number and tense.

A good example of this is seriation. There will be a point in a child's intellectual development when s/he can compare objects with respect to size. This means that if you gave the child a number of sticks, s/he could arrange them in order of size. Piaget suggested that a child who had not yet reached this stage would not be able to learn and use comparative adjectives like "bigger" or "smaller".

Object permanence is another phenomenon often cited in relation to the cognitive theory. During the first year of life, children seem unaware of the existence of objects they cannot see. An object which moves out of sight ceases to exist. By the time they reach the age of 18 months, children have realised that objects have an existence independently of their perception. The cognitive theory draws attention to the large increase in children's vocabulary at around this age, suggesting a link between object permanence and the learning of labels for objects.

Clearly there is some link between cognitive development and language acquisition; Piaget's theory helps explain the order in which certain aspects of language are acquired.

1.5.7 Limitations of Cognitive Theories

This theory does not explain why language emerges in the first place. Apes also develop cognitively in much the same way as young children in the first few years of life, but language acquisition doesn't follow naturally from their development. Bees develop the cognitive ability to respond to many shades of colour, but bees never develop any communication signals based on shades of color.

During the first year to 18 months, connections of the type explained above are possible to trace but, as a child continues to develop, so it becomes harder to find clear links between language and intellect. Some studies have focused on children who have learned to speak fluently despite abnormal mental development. Syntax in particular does not appear to rely on general intellectual growth.

1.5.8 Input or Integrationist Theories

In contrast to the work of Chomsky, more recent theorists have stressed the importance of the language input children receive from their care-givers. Language exists for the purpose of communication and can only be learned in the context of interaction with people who want to communicate with the person. Interactionists such as Jerome Bruner (1966,68) suggest that the language behaviour of adults when talking to children (known as child-directed speech or CDS) is specially adapted to support the acquisition process. This support is often described to as scaffolding for the child's language learning. Bruner also coined the term Language Acquisition Support System or LASS in response to Chomsky's LAD. It has been noted that the turn-taking structure of conversation is developed through games and non-verbal communication long before actual words are uttered.

Children do not hear sentences in isolation, but in a context. Many models of language acquisition assume that the input to the child consists of a sentence and a representation of the meaning of that sentence, inferred from context and from the child's knowledge of the meanings of the words

1.5.9 Limitations of Input Theories

These theories serve as a useful corrective to Chomsky's early position and it seems likely that a child will learn more quickly with frequent interaction. However, it has already been noted that children in all cultures pass through the same stages in acquiring language. We have also seen that there are cultures in which adults do not adopt special ways of talking to children, so child directed speech may be useful but may not be essential.

As stated earlier, the various theories should not be seen simply as alternatives. Rather, each of them offers a partial explanation of the process.

1.6 THE BIOLOGY OF LANGUAGE ACQUISITION

Human language is made possible by special adaptations of the human mind and body that occurred in the course of human evolution, and which are put to use by children in acquiring their mother tongue.

Most obviously, the shape of the human vocal tract seems to have been modified in evolution for the demands of speech. Our larynxes are low in our throats, and our vocal tracts have a sharp right angle bend that creates two independently-modifiable resonant cavities (the mouth and the pharynx or throat) that defines a large two-dimensional range of vowel sounds (Lieberman, 1984).

It is tempting to think that if language evolved by gradual Darwinian natural selection, we must be able to find some precursor of it in our closest relatives, the chimpanzees. In several famous and controversial demonstrations, chimpanzees have been taught some hand-signs based on American Sign Language, to manipulate colored switches or tokens, and to understand some spoken commands (Gardner & Gardner, 1969; Premack & Premack, 1983; Savage-Rumbaugh, 1991). Though artificial chimp signaling systems have some analogies to human language (e.g., use in communication, combinations of more basic signals), it seems unlikely that they are homologous. Chimpanzees require massive regimented teaching sequences contrived by humans to acquire quite rudimentary abilities, mostly limited to a small number of signs, strung together in repetitive, quasi-random sequences, used with the intent of requesting food or tickling (Terrace, Petitto, Sanders, & Bever, 1979; Seidenberg & Petitto, 1979, 1987; Seidenberg, 1986; Wallman, 1992; Pinker, 1994a). These contrasts sharply with human children, who pick up thousands of words spontaneously, combine them in structured sequences where every word has a determinate role, respect the word order of the adult language, and use sentences for a variety of purposes such as commenting on interesting objects.

This lack of homology does not, by the way, cast doubt on a gradualist Darwinian account of language evolution. Humans did not evolve directly from chimpanzees. Both derived from common ancestor, probably around 6-7 million years ago. This leaves about 300,000 generations in which language could have evolved gradually in the lineage leading to humans, after it split off from the lineage leading to chimpanzees. Presumably language evolved in the human lineage for two reasons: our ancestors developed technology and knowledge of the local environment in their lifetimes, and were involved in extensive reciprocal cooperation. This allowed them to benefit by sharing hard-won knowledge with their kin and exchanging it with their neighbors (Pinker & Bloom, 1990).

1.6.1 Maturational Changes in Brain

The maturation of language circuits during a child's early years may be a driving force underlying the course of language acquisition (Pinker, 1994; Bates, Thal, & Janowsky, 1992; Locke, 1992; Huttenlocher, 1990). Before birth, virtually all the neurons (nerve cells) are formed, and they migrate into their proper locations in the brain. But head size, brain weight, and thickness of the cerebral cortex (gray matter), where the synapses (junctions) subserving mental computation take place, continue to increase rapidly in the year after birth. Long-distance connections (white matter) are not complete until nine months, and they continue to grow their speed-inducing myelin insulation throughout childhood. Synapses continue to develop, peaking in number between nine months and two years (depending on the brain region), at which point the child has 50% more synapses than the adult. Metabolic activity in the brain reaches adult levels by nine to ten months, and soon exceeds it, peaking around the age of four. Synapses wither from the age of two through the rest of childhood and into adolescence, when

the brain's metabolic rate falls back to adult levels. Perhaps linguistic milestones like babbling, first words, and grammar require minimum levels of brain size, long-distance connections, or extra synapses, particularly in the language centers of the brain.

Similarly, one can conjecture that these changes are responsible for the decline in the ability to learn a language over the lifespan. The language learning circuitry of the brain is more plastic in childhood; children learn or recover language when the left hemisphere of the brain is damaged or even surgically removed (though not quite at normal levels), but comparable damage in an adult usually leads to permanent aphasia (Curtiss, 1989; Lenneberg, 1967).

Newport and Gleitman (1995) shows how sheer age seems to play an important role. Successful acquisition of language typically happens by 4 and is guaranteed for children up to the age of six, is steadily compromised from then until shortly after puberty, and is rare thereafter. Maturational changes in the brain, such as the decline in metabolic rate and number of neurons during the early school age years, and the bottoming out of the number of synapses and metabolic rate around puberty, are plausible causes. Thus, there may be a neurologically-determined "critical period" for successful language acquisition, analogous to the critical periods documented in visual development in mammals and in the acquisition of songs by some birds.

1.6.2 Dissociations Between Language and General Intelligence

Humans evolved brain circuitry, mostly in the left hemisphere surrounding the sylvian fissure, that appears to be designed for language, though how exactly their internal wiring gives rise to rules of language is unknown (Zurif, 2000). The brain mechanisms underlying language are not just those allowing us to be smart in general. Strokes often leave adults with catastrophic losses in language (Zurif, 2000; Pinker, 1994a), though not necessarily impaired in other aspects of intelligence, such as those measured on the nonverbal parts of IQ tests.

There are also syndromes showing the opposite dissociation, where intact language coexists with severe retardation. These cases show that language development does not depend on fully functioning general intelligence. One example comes from children with Williams Syndrome, an inherited condition involving physical abnormalities, significant retardation (the average IQ is about 50), incompetence at simple everyday tasks (tying shoelaces, finding one's way, adding two numbers, and retrieving items from a cupboard), social warmth and gregariousness, and fluent, articulate language abilities (Bellugi, et al., 1990).

1.6.3 Neural Networks

Some cognitive neuroscientists have created neural networks, or computer models, that can acquire some aspects of language. These neural networks are not preprogrammed with any rules. Instead, they are exposed to many examples of a language. Using these examples, the neural networks have been able to learn the language's statistical structure and accurately make the past tense forms of verbs. The developers of these networks speculate that children may acquire language in a similar way, through exposure to multiple examples.

1.7 LET US SUM UP

The topic of language acquisition implicates the most profound questions about our understanding of the human mind, and its subject matter, the speech of children, is endlessly fascinating. But the attempt to understand it scientifically is guaranteed to bring on a certain degree of frustration. Languages are complex combinations of elegant principles and historical accidents. We cannot design new ones with independent properties; we are stuck with the confounded ones entrenched in communities. Children, too, were not designed for the benefit of psychologists: their cognitive, social, perceptual, and motor skills are all developing at the same time as their linguistic systems are maturing and their knowledge of a particular language is increasing, and none of their behaviour reflects one of these components acting in isolation.

Learning anything about language acquisition at all, is only because a diverse set of conceptual and methodological tools has been used to trap the elusive answers to these questions: neurobiology, ethology, linguistic theory, naturalistic and experimental child psychology, cognitive psychology, philosophy of induction, theoretical and applied computer science. Language acquisition, then, is one of the best examples of the indispensability of the multidisciplinary approach called cognitive science.

1.8 UNIT END QUESTIONS

- 1) Describe some of the processes involved in language?
- 2) Why study of language is important for cognitive psychologists?
- 3) There is a universal course of development every child follows in the learning of language. Describe.
- 4) How do we acquire the ability to use language?
- 5) Compare and contrast the behaviourism and innateness theories of language acquisition.
- 6) Nature and nurture both influence the course of language development. Explain with empirical evidence.
- 7) Illustrate cognitive theory of language acquisition in detail.
- 8) Give a sample of an utterance one might reasonably expect to hear from an 18 month old child.
- 9) Give a detailed biological account of language acquisition.
- 10) Make a worksheet showing the initial stages of language acquisition in a child with elaborate examples and reference studies.

1.9 SUGGESTED READINGS AND REFERENCES

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UNIT 2 LANGUAGE PROCESSING (COMPREHENSION AND LANGUAGE EXPRESSION)

“Language is a process of free creation; its laws and principles are fixed, but the manner in which the principles of generation are used is free and infinitely varied. Even the interpretation and use of words involves a process of free creation.”

– Noam Chomsky

Structure

- 2.0 Introduction
- 2.1 Objectives
- 2.2 Functions of Language
- 2.3 Structure of Language
 - 2.3.1 Basic Units of Language: Phonemes and Morphemes
 - 2.3.2 Higher Levels of Linguistic Analysis
 - 2.3.3 Phase Structure of Sentences
 - 2.3.4 Structure and Deep Structure in Sentences
- 2.4 Processes in Language
 - 2.4.1 Production of Language
 - 2.4.2 Speech Perception and Comprehension
- 2.5 Language Development
- 2.6 Comprehensive Model of Language Processing
 - 2.6.1 Kintsch’s Model of Comprehension
 - 2.6.2 Propositional Representation of Text and Reading
- 2.7 Let Us Sum Up
- 2.8 Unit End Questions
- 2.9 Suggested Readings and References

2.0 INTRODUCTION

One form of knowledge shared by all human societies is the knowledge of language. Language is the principal means by which we acquire and express knowledge; thus, the study of how language is used is a central concern of cognitive psychology. In the previous chapter, we studied the modes of language acquisition; here we will do an overview of the research on the processes of language involving the comprehension and expression of language.

Language, like other cognitive functions, is a (dynamic) *process*. Such an enterprise requires that we examine the microstructure of the entire process as it occurs in real time. It is only through the careful examination of the temporal course of mental operations involved in the various levels of analysis underlying speech that we can hope to discover its nature.

How do we understand language, given its multifaceted encoding? One approach to this question centers on the psychological processes involved in speech

perception (Hickok & Poeppel, 2000). It also considers how listeners deal with the peculiarities resulting from the acoustic (related to sound) transmission of language. A, second, more linguistically oriented approach focuses on descriptions of the grammatical structure of language. Finally, a third approach examines the psycholinguistic processes involved in language comprehension at the discourse macro-level of analysis. All three approaches overlap to some degree and offer interesting insights into the nature of language, its use, and understanding.

2.1 OBJECTIVES

After reading this unit, you will be able to:

- Examine the basic features involved in the language processing;
- Explain the expression and comprehension of language;
- Elucidate the functions of Language;
- Analyse the structure of Language;
- Explain the processes in Language; and
- Describe Walter Kintsch's model of comprehension.

2.2 FUNCTIONS OF LANGUAGE

Language serves many functions, which are all related to the fundamental process of communication. Perhaps most important is that language conveys meaning and is part of almost all kinds of social interaction. Language conveys intentions, motives, feelings, and beliefs. Language is used to issue requests and commands; and is also used to teach and to convey information. Language is useful because it can represent ideas and events that are not tied to present. You can also describe abstract ideas, such as beauty and justice, as well as concrete objects of everyday experience. Thus, language is *symbolic*, in that speech sounds and utterances stand for or represent various objects, ideas, and events.

Regardless of whether we are considering spoken language, written language, or sign language, there are three elements of language expression and human communication that have been identified as operating in the speaker-listener situation: *speech acts*, *propositional content*, and *thematic structure*. A brief description from the analysis by Clark & Clark (1977) is as follows:

- i) **Speech Acts:** Speakers normally intend to have some influence on their listeners. To do so, speakers get the listeners to recognise the speakers' intentions. Indeed, failure to recognise these intentions can result in awkward situations. Speech-act theory holds that all utterances can be classified as to the type of speech act they represent. For example, speech acts may make assertions, make verbal commitments, convey thanks, give a warning, or issue a command. Typical examples of speech acts including the following: "I insist that you turn down the volume on the stereo" (a command); "What are your plans for weekend?" (a question); "I promise to pay you tomorrow" (a verbal commitment), symbolise ordering, questioning, committing etc, which are common *direct* speech acts.

Searle (1969) pointed out that some speech acts are *indirect*. When your mother asks if you live in a barn, a guest in your house asks if you are chilly,

they are conveying information about their desires, but in a rather indirect, nonliteral way. The meaning of any particular speech act, including whether it is direct or indirect, will depend on the *context* in which it is uttered (Gibbs, 1986), as well as its content.

- ii) **Propositional Content:** The second element of communication concerns the *propositional content* of a sentence. In communication, speakers want to convey certain ideas, and to do this, they must be sure that they are understood. Thus, the content around a speech act is very important. As a general rule, the propositional content of a sentence is used to describe certain states or events; it can be part of other propositions. For example, the sentence “The bright student received an A in Mathematics” expresses two separate propositions: “the student is bright” and “the student received an A in Mathematics.” Combined into a single sentence, the propositions convey what the speaker intends to convey. There is experimental evidence that we represent as propositions. For example, the more propositions contained in a sentence, the longer the time required to read the sentence (van Dijk & Kintsch, 1983)(discussed in detail in last section).
- iii) **Thematic Structure:** The third component in communication is *thematic structure*. To communicate effectively, good speakers pay careful attention to their listeners. Good speakers have to judge what listeners do and do know, keep track of where they are leading their listeners, and regularly examine any assumptions about the listeners’ knowledge of the topic being discussed. In short, the speaker must be able to make reasonably accurate judgments of the listener’s current level of understanding. All of these features are present in good teachers, entertaining and effective storytellers, and interesting conversationalists.

2.3 STRUCTURE OF LANGUAGE

A theoretical intervention about the process which leads to the understanding of an utterance in communication should involve two aspects. Firstly, the aspects of language linked to the recognition of the form of the utterance itself (phonology, morphology, and syntax); secondly, questions about how the meaning of what is understood can be defined, which are linked to semantics and pragmatics of the communication process. These two aspects cannot be separated, and in order to analyse the process of language, both are to be taken into consideration. Thus, to understand the language processes, it is fundamental to understand the basic structure of language first.

As should be evident by now, language can be divided into three basic parts, each with its own structure and rules: phonology, syntax (grammar), and semantics. The first of these, *phonology*, concerns the rules for pronunciation of speech sounds. The second aspect of language, *syntax*, deals with the way words combine to form sentences. And *semantics* focuses on the meaning of words and sentences.

2.3.1 Basic Units of Language: Phonemes and Morphemes

All languages are made of basic sounds called *phonemes*. Adult human beings can produce approximately 100 phonemes, and the English language is made up

of about 45 phonemes. Languages vary in the number of phonemes, ranging from as few as 15 to as many as 85. One reason why it is difficult for many Americans to learn foreign languages is that different phonemes are used. For instance, Germanic and Slavic languages contain phonemes never used in the English language. (Phonemes and morphemes have already been defined in the previous chapter).

2.3.2 Higher Levels of Linguistic Analysis

The study of speech sounds which make up a language is called *phonology*, and the study of how these sounds combine to produce morphemes is called *morphology*. However, psychologists are frequently interested in a more global analysis of language than is provided by phonology and morphology. Psychological investigations of language typically adopt words, phrases, sentences, or prose, rather than more elementary speech sounds, as the most fundamental unit of analysis.

There are several levels at which these higher-order analyses can be made.

- 1) First, one could analyse the *lexical content* of a sentence or of some other unit of language production. When a lexical analysis is performed, the question is simply, what words are used, and how many times they are used in this sample of language? Information gained from lexical analysis of language, such as that by Thorndike and Lorge, has proved to be very useful in predicting the ease with which different words can be learned in laboratory situations.
- 2) At another level of linguistic analysis, the syntactic content of language text may be investigated. In the study of syntax, interest is focused on the arrangement or ordering of words to form phrases and sentences. The question asked in this type of analysis is, how is this phrase (or sentence) structured? Psychologists and linguists interested in syntactic theory have attempted to specify rules that account for the productivity of language (Chomsky, 1985). The set of rules indicating how the elements of the language may be combined to make intelligible sentences is referred to as a *grammar*. Although a large number of different grammars have been proposed, there is little agreement about the necessary features of an adequate grammar.
- 3) Another level of analysis of language is the one that considers the *semantic content* or meaning of passage. This perspective on language results in the asking of questions such as the following: What does the passage communicate? What is the meaning of this particular sentence?

Word meaning is a function of the interaction between word features and the extent to which they match those belonging to certain prototypical and nonprototypical contexts (Lakoff, 1987). Here, both feature theory and prototype theory are seen as important.

The critical role of semantics is not under question and has been clearly demonstrated in a number of psychological investigations. In general, current views of semantics and comprehension view the listener (or reader) as an active participant who formulates hypotheses about subsequent input based on context (both verbal and situational), on knowledge of constraints in the language, and on knowledge of the world. This is in contrast to the more

passive view of the comprehended as someone who waits for the input before acting upon it.

2.3.3 Phase Structure of Sentences

In order to understand language in an adult, it is necessary to examine the structure of sentences. At one level of analysis, a sentence can be regarded simply as a string of phonemes. At another level, a sentence can be regarded as series of morphemes, which are grouping of phonemes. From this viewpoint, however, the sentence is viewed as a string of words. Linguists have found it more useful to describe a sentence in terms of *phrases*, which are grouping of words.

Analysis of a sentence into its various phrases describes the *phrase structure* of a sentence. A sentence is viewed as composed of two basic phrases, a *noun phrase* and a *verb phrase*, which in turn are composed of subcomponents.

Figure 2.1 shows the phrase structure of a simple sentence, “The boy ate an apple.” The noun phrase is composed of a *determiner* and a *noun*, and the verb phrase is composed of a *verb* and *noun phrase*; the latter noun phrase is also composed of a determiner and a noun. Pause in speech usually reflect underlying phrase structure. For example, we are most likely to say, “The boy...ate...an apple,” pausing ever so briefly after *boy* and *ate*. We are not likely to say, “The...boy ate...an apple,” or “The... boy ate an....apple,” grouping *boy*, *ate*, and *an*. While in normal speech a speaker may search and grope for a particular word and, thus, alter the pauses, the listener still tends to understand the message.

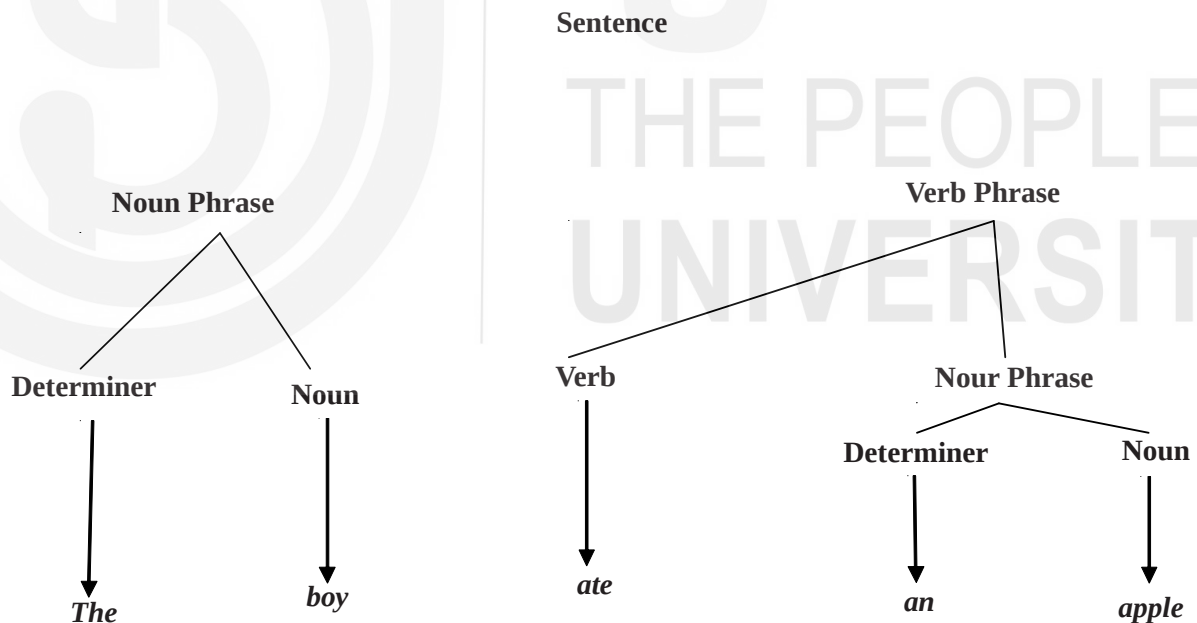


Fig. 2.1: Phrase structure in a sentence represented by a tree diagram (adapted from Hunt & Ellis, 2006)

2.3.4 Structure and Deep Structure in Sentences

The *surface structure* is the organisation that describes the sequences of phrases in a sentence as it is actually spoken (or read) and reflects the phonological realisation of the complex, underlying linguistic structure.

Deep structure, in contrast, refers to the underlying structure that includes the relevant string of linguistic units, the grammatical requirements for lexical (word)

selection, and the grammatical relations between words in sentences. The deep structure of a sentence, thus, specifies the derivations of both its surface structure and meaning.

Consider the sentences, “Rohit threw the ball” and “The ball was thrown by Rohit.” Both sentences convey the same meaning despite the fact that they sound different. Hence their deep structure is same. But consider the sentence “The lamb is ready to eat,” which can have two meanings. The lamb may serve as food to be eaten, or as an animal, the lamb is prepared to eat food. Thus, the deep structure can vary within the same sentence, depending on what meaning the speaker wishes to convey. Evaluate the meaning of the following ambiguous sentences” “Visiting relatives can be a nuisance,” “the corrupt police can’t stop drinking.”

Sentences with essentially a single deep structure and two or more surface structures are *synonymous*. Sentences with different deep structures and the same surface structure are *ambiguous*. Thus, important problem remaining concerns the theoretical rules by which the deep structure of a sentence comes to be realised in a particular surface structure. Rules for the specification of this linkage process, called *transformational rules*, have been developed by Noam Chomsky (Chomsky, 1965, 1975) and other linguists.

Transformational rules have clear implications about what features of sentences human beings do store in memory. If the sentence is simple, then features of the surface structure may be stored. As sentences become more complex, what is thought to be stored is some underlying base structure, or *schema*, plus one or more “footnotes” that serve as rules necessary to regenerate the sentence in its original surface form. Thus, what is stored is some coded representation of the complex sentence.

Information contained in a linguistic message tends to be comprehended, and sometimes is remembered, in syntactically defined chunks, although semantically based chunking also may be used, depending on the demands placed upon the listener and the nature of the material (Marschark, 1979). Thus, the phrase structure of a sentence appears to play an important organisational role in language processing at a very basic level (Ferreira & Clifton, 1986).

Self Assessment Questions

1) Explain language in your words.

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2) What are the three functions of language?

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3) Explain surface structure and deep structure.

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2.4 PROCESSES IN LANGUAGE

In this section we will examine some basic processes in language. The focus is on three processes: (i) production of language, (ii) speech perception and comprehension, and (iii) language development.

2.4.1 Production of Language

The beginning of a dialogue is usually the production of speech by one of the participants, although a gesture or other sign may initiate such an interaction and have its origins in a similar verbal plan (McNeil, 1985). But, before uttering a sentence or manually expressing any information, the speaker must do some planning based on the intended effect the utterance is to have on the listener; based on the speaker's knowledge of the listener's scope of understanding (example, is the listener familiar with the topic?); and based on the syntactic, semantic, and *pragmatic* (or social) form that the production and its desired effects requires. Thus, speaking is very much an *instrumental act*, which is to say that speakers talk in order to produce an effect of some kind.

The process of speaking is basically concerned with planning and execution. But just how is speech planned and executed? Clark & Clark (1977) described a rough outline of this process, which involves five steps. The first step for speakers is to decide on the kind of discourse to be initiated, which is the issue of *discourse plans*. Do they want to engage in a conversation, to describe an event, to give instructions, or to regale a friend with a humorous story? Each type of discourse has a particular structure, and speakers must plan their utterances to fit that structure.

For example, if you are telling a joke, you first describe the setting or context, then describe the sequence of events, and end with the punch line. If you fail to follow this structure, you obviously will not be an effective joke teller. If you give away the joke by accidentally telling the punch line before the appropriate time, you will defeat your purpose. Similarly, instructions and conversations have an orderly structure.

One set of guidelines that speakers and listeners seem to follow to foster good communication during a conversation has been described by Grice (1975) and others (e.g., Levelt, 1989). These "Gricean Maxims" are:

Quantity: Avoid running off at the mouth.

Quality: Don't lie or stretch the truth.

Relation: Avoid making statements irrelevant to the topic of conversation.

Manner: Avoid vague or ambiguous statements.

Failure to follow these maxims often results in a *conversational implicature*. For example, imagine that you are reviewing an applicant's letter of recommendation for a highly technical job, and the letter reads as follows:

I am writing a letter on behalf of Gopal Bhatnagar. Gopal dresses very well and has a charming wife. He also drives a nice automobile and sings in his church's choir. Thank you.

Would you hire Gopal based on this letter? Probably not. Clearly, the content of this letter violates the Relation Maxim. Because of this, the letter writer has conversationally implied that John is not the person for the job. Speakers (and letter writers) usually adhere to these Gricean Maxims; but, as this example demonstrates, it is quite informative when they don't.

Planning discourse is planning at global level. The second stage of speech production involves *planning of sentences*, the components of discourse. Once the nature of discourse is decided, specific sentences that will accomplish the objective must then be selected. The speech act, the propositional content, and the thematic structure need to be determined. The order in which sentences are produced and the type of information to be conveyed must be thought about. For example, suppose you are describing your new house. You might first describe the location; next, you might describe the overall type of house; then you might proceed to describe the floor plan and arrangement of rooms and, finally, give specifics of each room. Notice that there is a structure that involves going from global, or general information, to progressively more specific details.

The third phase of speech production deals with *constituent plans* of the sentence. Once a sentence is decided on, its components must then be planned. The appropriate words, phrases, and so forth must be picked out and put in the right order. These first three phases describe three levels of planning. At the most general level, planning is directed towards the type of discourse. At the next level, planning concerns the type of sentence to be uttered. At the third level, planning deals with specific components of the sentence.

An interesting feature of slips of the tongue is that they point out regularities in the planning stages of productions. For example, slips are seldom "illegal" combinations of sounds for the language; morphemes tend to slip as entire units (Clark & Clark, 1977). Some classic slips are known as "bloopers" in the world of radio and television. Some bloopers are fairly obvious. For example, an announcer for the 'Friendly Homemaker Program' said, "And now we present our homely friendmaker. Another example is a remark of the commentator covering visit of the king and queen of England: "When they arrive, you will hear a 21 son salute."

The fourth phase of speech production deals with what is called the *articulatory program*. This concerns the plans for the execution of speech, which is a coordinated sequence of muscular contractions in and about the mouth. And the final phase of speech production is *articulation* itself. This is the actual output of speech. Interested readers are referred to Clark & Clark (1977) and Levelt (1989) for a detailed discussion of planning and execution of speech.

2.4.2 Speech Perception and Comprehension

To understand speech is crucial to human communication. Hence, speech perception is fundamental to language use in our day to day life. We are able to perceive speech with amazing rapidity. On the one hand, we can perceive as many as fifty phonemes per second in a language in which we are fluent (Foulke & Sticht, 1969). On the other hand, we can perceive only about two thirds of a single phonemes per second of nonspeech sounds (Warren et al., 1969). This is why foreign languages are difficult to understand when we hear them. Even if we can read them, the sounds of their letters and letter combinations may be different from the sounds corresponding to the same letters and letter combinations in our native language.

The comprehension of speech begins with the perception of raw speech sounds. Comprehension starts where speech production ends. Speakers produce a stream of sounds that arrive at the listener's ears; then, listeners are able to analyse the sound patterns and to comprehend them. Speech perception is not, however, the simple identification of sounds.

It involves the complex processes of encoding and comprehension. In other words, interpretative processes, meaning, contextual influences, and the like play important roles in speech perception. Thus, the transformation from raw speech sounds to propositions in memory is a complex process. The physical signal that reaches the ear consists of rapid vibrations of air. While the sounds of speech correlate with particular component frequencies, there is no direct one-to-one correspondence between the sounds of speech and the perception of listeners.

Recognition of words is very much dependent on context, explanations, and knowledge. For example, a hungry child can interpret the question "Have you washed your hands for dinner?" as a call to come directly to dinner (i.e., as indirect speech act rather than a direct question).

The role of context also can be easily seen in complete sentences in which context allows words to be inferred quite easily. For example, the sentence "The young girl was awakened by her frightening d...." allows listeners to infer *dream*. There is no need to think about what the word might be; it just seems to pop out automatically.

A similar context effect was studied in the laboratory of Warren (Warren & Obusek, 1971) using phonemes. Subjects were read sentences that had a single speech sound obscured. For example, the sentence "The state governors met with the respective legislatures convening in the capital city" had the first *s* in *legislatures* masked by a coughing sound. The experimenter then asked the subjects to identify where the cough had occurred. [The results indicated that subjects somehow "restored" the missing *s* sound and were unable to locate the interjected cough.]

The phenomenon, appropriately called *phonemic restoration*, has been shown to be even more likely when more than a single word can result from the restoration (example: "_egion" can become either "legion" or "region"), indicating an active word-searching process in speech perception (Samuel, 1987).

Many people have the impression that the words they hear are distinct, separate combinations of sounds, but this impression is not correct. Cole (1979, 1980)

and other speech researchers have demonstrated that words usually run together as sound patterns. This is seen by use of a spectrograph, an electronic device for measuring the variations in energy expended when a person talks. Moreover, it is often the case that a single word cannot be recognised correctly when it is taken out of its sentence context. This was shown some years ago by Pollack and Pickett (1963), who played different segments of a normal conversation for subjects. When the subjects heard just one word from the conversation, it was often incomprehensible. Without the context of the meaningful sentence, the single word could not be understood.

More generally, an important feature of speech perception is that speech is not comprehended simply on the basis of the sounds *per se*. Rather, speech is comprehended on the basis of many additional factors (e.g., intentions, context, and expectations) from which an interpretation of what the speaker says is constructed. (Tyler & Marslen-Wilson, 1986; see Paivio & Begg, 1981, for a review).

One main approach equates processes of speech perception with processes of auditory perception of other sounds. These kinds of theories emphasises either template-matching or feature-detection processes. Such theories postulate that there are distant stages of neural processing. In one stage speech sounds are analysed into their components. In another stage these components are analysed for patterns and matched to a prototype or template (Kuhl, 1991; Massaro, 1987). One theory of this kind is the phonetic refinement theory (Pisoni et al., 1985), which says that we start with an analysis of auditory sensations and shift to higher level processing. A similar theoretical idea is embodied by the TRACE model (McClelland & Elman, 1986). According to this model, speech perception begins with three levels of feature detection: the level of acoustic features, the level of phonemes, and the level of words. According to this theory, speech perception is highly interactive. Lower levels affect higher levels and vice versa.

One attribute of these theories have in common is that they all require decision-making process above and beyond feature detection or template matching. Thus, the speech we perceive may differ from the speech sounds that actually reach our ears. The reason is that cognitive and contextual factors influence our perception of sense signal. For example, the phonemic-restoration effect involves integrating what we know with what we hear when we perceive speech (Samuel, 1981; Warren, 1970).

2.5 LANGUAGE DEVELOPMENT

Language acquisition and development follows a fairly orderly course. (This order has been discussed in detail in the earlier chapter on Language Acquisition). Here we will focus on development of *semantics* which ultimately help the child in comprehending the language.

Making speech sounds is only the first step in acquiring language. The sounds must come to represent objects, symbols, and events in the child's environment and they must acquire *meaning* for the child.

Children are familiar with many aspects of their environment before they learn to speak. Their parents, toys, pets, siblings, and household objects are familiar

stimuli. At this early stage of language development, their task is one of learning to associate particular environment stimuli with particular sound symbols and responses. For example, they must learn to associate the sight of mother with the sound of *Mama*.

Only when such associations are acquired, the speech sound come to represent or symbolise a specific object or event for the child. These associations are only a part of language development. Thus, the development of meaning begins with the acquisition of associations between objects/events and speech sounds.

One popular view of the acquisition of word meaning is that children learn semantic features and then attempt to apply an original word that includes the features to objects that share those features. For example, a child may learn the word *ball* and then *overgeneralise* it to other round objects such as moon and orange.

Gradually, the child begins to construct more complex sentences that take on the characteristics of adult language. This is an enormously challenging task (Brown, 1973). What the child learns are sets of *grammatical*, *semantic*, and *pragmatic* rules for constructing sentences. Usually, children are unable to verbalise the rules, but their linguistic *performance* indicates that they do possess linguistic competence, the knowledge necessary to produce all and only those situations of a given language.

Indeed, many adults who speak grammatically acceptable English are unable to specify the rules they use. But these rules allow us to generate the almost infinite number of sentences. One of the best pieces of evidence for learning syntactic rules is the phenomenon of overgeneralisation. For example, children learn to say *went* correctly, apparently by rote, then learn the rule of forming the past tense by adding *ed*, and then incorrectly as *goed*. They later learn the exception to the rule and go back saying *went*. Similar overgeneralisations occur in deaf child's acquisition of sign language.

This brief description only begins to sketch some of the complexities of language development. What is clear is that young children have an enormously complex task in learning to speak, read, and use language in a meaningful fashion. The fact that human beings can acquire and use language emerges as a remarkable achievement.

Finally, relating language development to the earlier discussion on speech acts, there have also been some interesting findings. For example, it appears that younger children view the meaning of "I Promise" differently than do older children and adults. According to philosopher Sourly (1969), certain conditions must be present for a sincere promise to be made.

One condition is that the person making the commitment actually intends to carry out the promised action. A second condition is that it is apparent that the person to whom the promise is directed desires the action to be carried out. In a recent study, Bernicot & Laval (1996) report that 3-year-olds have difficulty understanding only the second condition. But, by age 10, children evaluate both conditions equivalently well in determining the outcome of a scenario (concerning the occurrence of the promised activity), where these conditions were manipulated.

These findings indicate that the meaning of “I Promise” is quite different, depending on the age of the child to whom it is said. Specifically the understanding of the contextual circumstances underlying the making of a verbal commitment increments with age. Initially, children are primarily concerned with whether the promised activity simply occurred; as they grow older, they begin to grasp the intentions of the speaker in evaluating the likely outcome of that activity (Astington, 1988).

2.6 COMPREHENSIVE MODEL OF LANGUAGE PROCESSING

This chapter has progressed systematically from the simple linguistic entities (phonemes and morphemes), to syntax and grammar, to speech perception and comprehension. One might wonder, whether there are any comprehensive theories of language. In fact there are many. One by Kintsch is particularly significant because it incorporates many bits of wisdom from earlier studies and, at the same time contains a model of the mind. Let's discuss now the principal components of the most influential, extensive and comprehensive model of language processing by Kintsch and van Dijk (Kintsch, 1974, 1979, 1988, 1990; Kintsch & van Dijk, 1978) briefly.

2.6.1 Kintsch's Model of Comprehension

This model of comprehension is more than a system that deals with the way textual information is understood. It is a theory that cuts across many topics in cognitive psychology, including memory and comprehension of the written and spoken language. Comprehension is dependent on two disparate sources that are similar to top-down and bottom-up processing. [Borrowed from computer language, *bottom-up* processing is cognitive processing initiated by the components of a stimulus pattern which, when summed, lead to recognition of the whole configuration; whereas *top-down* processing is hypothesis-driven recognition of the whole stimulus configuration, which leads to the recognition of component parts.] At the highest level is the goal schema, which decides what material is relevant. At the opposite extreme of the model is the text.

The model is based on a proposition. A proposition is an abstraction, and, as such, it is difficult to define concretely. However, some characteristics of propositions can be identified: they are abstractions based on observations (such as reading text material or listening to a speaker); they are retained in memory and follow the laws governing memory processes; and, in Kintsch's system, they consist of a predicate and one or more arguments. Predicates corresponds to verbs, adjectives, adverbs, or connectives in the words a person reads or hears. This is called the *surface structure*, a term already discussed in previous sections. Arguments correspond to nouns, noun phrases, or clauses. The model is illustrated with the following little story:

The Swazi tribe was at war with a neighbouring tribe because of a dispute over some cattle. Among the warriors were two unmarried men, Kakra and his younger brother Gum. Kakra was killed in battle.

The first sentence is divided into five groups: the swazi tribe....was at war with....a neighbouring tribe.... because....a dispute over some cattle. According

to coherence analysis of this sentence, only first three of the factors are in working memory. The predicate “was at war with” is considered the most important part of this sentence insofar as comprehension of the story is concerned. The other parts are clustered around it.

A significant feature of the model is that the initial processing of the text is assumed to take place in Short Term Memory (STM), which we know has limited capacity. Because of this constraint, only a portion of the propositions is held in memory. With the reading of the second sentence, some of propositions from the first sentence are still vital in STM. The reader tries to connect the old and new propositions but finds no match between them.

Failing to find a match between the propositions in STM, the reader searches Long Term Memory (LTM) for a possible match. This search in the LTM is called *reinstatement search* and is one reason that text material may be hard to read. In the example, the lack of a match between propositions in the first and second sentence requires the reader to construct a new network for the ideas and to attempt to relate the two sentences.

One inference that the reader makes is that the two men were members of the Swazi tribe, a reasonable conclusion even though that the fact is not stated directly. With the reading of more sentences, the semantic network begins to get more complicated and interrelated. The reading of the sentence “Among the warriors were...., Kakra and.....” Retains in memory the names of the men, which can easily be related to the information in the last sentence “Kakra was killed in Battle.”

2.6.2 Propositional Representation of Text and Reading

As stated before the model of comprehension holds that the underlying unit of memory for text material is the proposition. Additionally, the model predicts that sentences of greater propositional complexity are more difficult to comprehend than sentences with simple propositional structure, even if the surface complexity of the two sentences is about the same. Kintsch and Keenan (1973) designed an experiment to test this prediction. A sample from many experiments is reported here.

Subjects were asked to read ten sentences, all of which had about the same number of words but varied greatly in the number of propositions. Some sentences had as few as four propositions, and others had as many as nine. For example, read the following two sentences:

Romulus, the legendary founder of Rome, took the women of Sabine by force.

Cleopatra’s downfall lay in her foolish trust in the fickle political figures of the Roman world.

Which sentence was more difficult to read? If you are like the subjects in Kintsch’s and Keenan’s experiment, you had more difficulty with the sentence about Cleopatra than the sentence about Romulus. Even though the surface complexity of the two sentences is about the same, they differ markedly in the number of propositions and the macrostructures that are required to interconnect the propositions.

In the Kintsch's and Keenan's experiment, subjects were presented with sentences similar to those just discussed above by means of slides. The subjects were asked to read each sentence and then to write it. They could then advance the slides and see the next sentence. Time taken in reading each sentence was noted. The authors found an extraordinarily consistent relationship between the number of propositions and the time required to read the sentences.

2.7 LET US SUM UP

In all, the approaches that have been taken in exploring many of the issues involved in the perceptual analysis of language and lexical processing merely scratch the surface of the complexity of both theory and fact that must be developed to provide a sufficient characterisation of the cognitive system. Language processing requires a multidisciplinary examination. To conclude, we can say that, like many other cognitive process, language processing is a very dynamic and complex process. No single method, function or theory can explain the process of language completely in itself; only a comprehensive approach should be appropriate and applied for the comprehension of language.

2.8 UNIT END QUESTIONS

- 1) Note the various experimental tasks that have been used to study language comprehension. Have you run into any of them before in this course?
- 2) It is intuitively obvious that context facilitates word interpretation, but how can it interfere with interpretation?
- 3) What is the role of context and expectations in the interpretation of speech? How has the influence of context been studied experimentally?
- 4) What are several major features of language development?
- 5) Compare and contrast the role of speech perception, syntax and semantics in the development and understanding of language.
- 6) What are the different processes involved in language comprehension?
- 7) The exposition of Kintsch's model is necessarily abstract and therefore difficult to comprehend. Preserve in your reinstated searches! See if you can use it to deal with a new example of text selected from another course.
- 8) What factors are included in Kintsch's model? How does the reader enter into this model?
- 9) Give an example of a humorous violation of one of Grice's four maxims of successful conversation.

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UNIT 3 MULTILINGUALISM AND COGNITION

“To have another language is to possess a second soul.” — Charlemagne (742/7 – 814), King of the Franks

Structure

- 3.0 Introduction
- 3.1 Objectives
- 3.2 Multilingualism — Basic Concepts
 - 3.2.1 The Structure of Multilingualism
 - 3.2.2 Multilingualism in India
- 3.3 Multilingualism and Cognition
 - 3.3.1 Relations Between Languages and Their Users
 - 3.3.2 Rule-governed Language Choice
 - 3.3.3 Mixing is Rule-Governed Too
- 3.4 Multilingualism and Thinking
 - 3.4.1 Other Benefits
- 3.5 Acquisition of a Second Language
 - 3.5.1 Single-System Versus Dual-System Hypotheses
- 3.6 Neural Mechanism of Multilinguals
- 3.7 Let Us Sum Up
- 3.8 Unit End Questions
- 3.9 Suggested Readings and References

3.0 INTRODUCTION

Multilingualism is the natural potential available to every normal human being rather than an unusual exception; it is only the environmental factors which may fail to provide the opportunity to learn another language that produce monolingual speakers: “Given the appropriate environment, two languages are as normal as two lungs” (Cook, 2002).

Every child is born with a language acquisition device having innate properties that plays a role in acquiring knowledge of language. This innateness is a biological endowment that Chomsky refers to as “Principles and Parameters”. According to this theory, there is a universal grammar – where “Principles” are general features, while “parameters” are variables left open in the statement of principles that account for the diversity found in languages. Grammar is a collection of choices (example, a choice between SOV and SVO patterns of sentences). They define the limited numbers of grammatically permitted choices from the universal grammar menu of options. There are also lexical facts. Once the vocabulary is learnt and grammatical patterns are fixed, the whole system falls in its place and general principles programmed into general organ, just churns away to yield all the particulars of the language concerned (Chomsky as quoted in Jenkins, 2000).

In other words, there are different grammatical systems based on the choice of different parameters, when the child is exposed to them, his/her innate capacity

gets activated and he/she acquires knowledge of the rules of the language while using it for communication. When the child is exposed to more than one such linguistic system, he/she acquires more than one language and is known as multilingual.

3.1 OBJECTIVES

After reading this unit, you will be able to:

- Define basic concepts and structure of multilingualism;
- Explain multilingualism and cognition;
- Define acquisition of language; and
- Explain neural mechanism of multilinguals.

3.2 MULTILINGUALISM – BASIC CONCEPTS

Multilingualism is the knowledge of more than one language by a person or within a social group; it assumes the ability to switch from one language to another in speech, in writing, or in reading. Other terms describing this phenomenon include bilingualism, polylingualism, plurilingualism, diglossia, and languages-in-contact. Multilingualism may be personal, social, or intersubjective. A generic term for multilingual persons is *polyglot*. *Poly* (Greek word) means “many”, *glot* (Greek) means “language”; and for the monolinguals is *monoglot*. *Personal multilingualism* refers to the knowledge and verbal behaviour of an individual, not necessarily shared by the whole community. *Social multilingualism* refers to the communicative practices of a nation, tribe, or other social group that sustains two or more languages. As in India, nearly 200 languages are spoken by its natives.

3.2.1 The Structure of Multilingualism

For many years, the popular belief was that a multilingual person should have learnt all of his or her languages simultaneously in early childhood and that he or she should have a native — like oral and written competence in all of them (Bloomfield 1933).

Today, a broader definition is more common. Accordingly, a person may be called multilingual if s/he uses his or her languages on a regular base and is able to switch from one to another where ever it is necessary, independently from the symmetry of his/her command of the languages, of the modalities of acquisition and of the distance between the varieties (Haugen 1953, Oksaar 1980 & Grosjean 1982). Thus, an Indian guest worker who learnt enough Swiss German dialect for his struggle for life in Switzerland may be considered bilingual with the same right (but not, of course, in the same way) as an interpreter working at the European Union and having systematically extended his or her ‘native’ French-English bilingualism.

Generally speaking, multilingualism is of two kinds: *Elite* – Language learned in a formal setting through planned and regular instruction as in a school system. *Neighborhood* – Here the language is acquired in a natural setting, acquired through the interaction with people speaking different languages. Theoretically

bilingualism is referred to as — *additive and subtractive bilingualism*. In *additive bilingualism*, a second language is acquired in addition to a relatively well-developed first language. In *subtractive bilingualism*, elements of a second language replace elements of the first language.

Researchers also distinguish between *simultaneous bilingualism*, which occurs when a child learns two languages from birth, and *sequential bilingualism*, which occurs when an individual first learns one language and then another (Bhatia & Ritchie, 1999). Either form of language learning can contribute to fluency. It depends on the particular circumstances in which the languages are learned (Pearson & associates, 1997).

It is known, however, that infants begin babbling at roughly the same age. This happens regardless of whether they consistently are exposed to one or two languages (Oller & associates, 1997). In the United States, many people make a big deal of bilingualism, perhaps because relatively few Americans born in the United States of nonimmigrant parents learn a second language to a high degree of fluency.

In other cultures, however, the learning of multiple languages is taken for granted. For example, in parts of India, people routinely may learn as many as four languages (Khubchandani, 1997). In Flemish-speaking Belgium, many people learn at least some French, English, and/or German. Often, they learn one or more of these other languages to a high degree of fluency.

No society or state has just one language, nor can language be isolated from culture. Societies are multilingual because of minorities that live within the dominant language group, and also because the official language itself presides over numerous dialects. In the Austro-Hungarian Empire, many linguistic and cultural communities had their own territories in a common state, dominated by German.

Language cannot be isolated from culture, because every language is a repository of values, images and memories: the semiotics of culture. The boundary between the semantics of language and the semiotics of culture is blurred, so that multilingualism shades into multiculturalism.

At the end of the 20th century, one or another form of multilingualism affect 60 per cent of the world's population. In other words, monolingualism is a boundary case of multilingualism, originated by very specific cultural conditions — and bilingualism is a particular form of multilingualism.

3.2.2 Multilingualism in India

India is said to be a socio-linguistic giant and the nerve system of this giant is multilingualism. “Indian multilingualism is huge in size, having 1620 mother tongues reduced to 200 languages....With the population of many of minorities larger than European countries”(Annamalai E. 2001).

This multilingual character of India is represented by its metropolitan cities like Mumbai and New Delhi, where people from all over come and settle down. For example, in Mumbai every child is exposed to at least four languages right from its infancy (Pai, 2005). Government of India has introduced the Three Language

Formula in its educational system, which means every child has to study two more languages other than their first language. The two languages are introduced simultaneously at upper primary level.

3.3 MULTILINGUALISM AND COGNITION

What all this means is that the monolingual approach is neither appropriate nor adequate for the investigation of language use in a society where multilingualism was endemic and where, for the education at least, monolingualism was the exception and not the norm” (Trotter, 2000).

3.3.1 Relations Between Languages and Their Users

Multilingualism is a particularly timely issue concerning language competence. A state of multilingualism may be achieved *naturally*, when a person grows up with two parents speaking different languages, or is a member of a minority, or lives in a multilingual community. In many parts of the United States, children are exposed to two or more languages as they grow up. Some children learn one language at home and another in a school setting.

Other children learn both languages at home, where, for example, the grandparents speak one language to the child, but the parents and siblings speak another. Still other children immigrate to this country speaking one language and then learn a second language in school once they are settled in their new environment. It may also be *acquired* later in life, through immigration or learning. Regardless of how one actually learns his or her languages, the result is an individual who has a greatly enhanced ability to think and communicate.

In terms of language processing, multilingualism offers a rich source of information about the organisation and use of the structure and processes of language already discussed in earlier chapter – not only concerning bilinguals or multilinguals but monolinguals as well.

Participant languages may be associated with different communicative media: conversation, writing, reading, and symbolic systems can use different, and not necessarily overlapping, languages. Three recent issues about multilingualism are briefly explored here:

- 1) The first concerns “*code-switching*”, the ability of multilinguals to select words from either of their languages during the course of uttering a sentence. Code switching maximizes the bilingual’s ability to convey his/her intended message to another bilingual and to understand another bilingual’s code-switching message.

What is fascinating is that code-switching often requires no additional time (and may, in fact, use less time) than when words from only one language are selected or perceived. One interesting study of this ability is by Peynircioglu & Tekcan (1993). In this study monolinguals and bilinguals searched a completed crossword puzzle for words in their language (Turkish and English). The bilinguals were equivalent to the monolinguals in the time they took to locate words in only one of their languages. But bilinguals were faster than monolinguals when they collectively located words in either of their languages. This finding indicates an advantage for bilinguals over

monolinguals in word recognition, which can be demonstrated when they are allowed to use a strategy of identifying all of the words they know (from both languages).

- 2) The second important issue concerns the treatment of lexical (grammatical) and semantic knowledge by multilinguals. One theoretical view places lexical knowledge in language-specific memory stores but semantic knowledge in a common conceptual memory store (Kroll & Sholl, 1992), whereas the other theoretical view places both types of knowledge in language-specific memory stores (Paivio, 1986).

The first theory predicts, for example, that semantic processing of a word in one language (e.g., translating a word presented in a categorized list into another language) should facilitate memory for that word (relative to translating that word when it is presented in a random list), whereas the second theory predicts that no such facilitation would take place (because contacting the meaning of a word in one language should not involve contacting the meaning of the word in other language).

To date, the evidence supports the first theory, known as “*Concept Mediation*” account, especially in fluent multilinguals (Amrhein & Sanchez, 1997; De Groot, Dannenburg, & Van Hell, 1994; Kroll & Sholl, 1992).

- 3) The third issue concerns how language familiarity influences a person’s ability to correctly identify another person’s voice. In a study conducted by Goggin, Thompson, Strube, & Simental (1991), English monolinguals and Spanish-English multilinguals heard texts read by the same person in either English, Spanish, or Spanish-accented English. A short time later, these subjects then heard a voice “line-up” of individuals reading a different text, again in either English, Spanish, or Spanish-accented English. Goggin & colleagues (1991) found a distinctly different pattern in the responses for monolinguals and bilinguals. For monolinguals, actual correct identifications were highest for their respective language. However, for bilinguals, correct identifications were generally the same across the three voice types.

Collectively, these findings indicate that bilinguals’ knowledge of two languages aids in their identification of the voice source of the messages they encounter and represents an interesting interaction between speech perception and higher level of language analysis. These findings also represent an advantage multilinguals have over their monolingual counterparts.

3.3.2 Rule-governed Language Choice

How does a multilingual person make an appropriate choice from among the varieties that constitute his/her repertoire? There is consensus among specialists that this choice is not arbitrary but governed by rules (Grosjean 1982, 145). Macrosociolinguistic research established the existence of domains appropriate for the use of one or the other language in diglossic societies (Fishman 1967).

Multilinguals would thus choose the appropriate variety taking into account whether it is a private or public affair, whether the conversation concerns the professional world or leisure activities, religion or education, etc. Where domains entwine (e.g. when an adolescent speaks with a minister [religion] about football [leisure] in the school building [education]), individual factors are isolated and pondered over. Language choice would be determined by characteristic bundles

of situational factors (Grosjean 1982). The same applies to heterogeneous diglossic societies. In all these cases, the value of each language is thoroughly appreciated. By choosing one or the other variety of his/her repertoire, the multilingual speaker makes the most rewarding use of his communicative resources.

3.3.3 Mixing is Rule-governed Too

Sometimes the choice of the appropriate language is not evident. Multilinguals can choose between a monolingual mode and a bilingual mode (Grosjean 1985), i.e. between monolingual and bilingual speech (Lüdi & Pym, 1984) respectively.

In the first case, the language that is not used is ‘switched off’ as far as possible.

In the second case, the speaker’s whole repertoire is activated. Possible criteria for the choice of the monolingual or bilingual mode are: the interlocutors’ repertoire, the degree of formality of the situation, normative representations of the interlocutors, etc. In other words, the situation is not ‘automatically’ bilingual even if both interlocutors are similarly bilingual. Bilingual mode requires a — locally established — mutual agreement on its appropriateness. This holds true for balanced as well as for unbalanced bilingualism (e.g. in the case of learners).

Systematic observations of examples like this have led to the hypothesis that there are rules and norms that overlap single languages and govern the harmonic, i.e. the ‘grammatical’, mixing of elements from different languages. It may be assumed that the matrix language chosen for various reasons (level of competence of the speaker, presumed level of competence of the audience, conformity with the situation) is activated and provides the cognitive scaffolding for the semiotic organisation of a representation (Talmy, 1985, 1995).

Searching for the appropriate words for what he wants to say, the speaker then scans both of his lexica (or both subsets of his global bilingual lexicon). To fill the gap of words he does not know, that are momentarily not accessible or that may not even exist in the matrix language — or to achieve a special discourse effect —, he will switch to the embedded language. But this is only possible if the lemma of the embedded language word matches the slot provided by the matrix language.

If this is not the case, the speaker will choose to switch to the embedded language for a larger stretch and produce an “*embedded language island*” (Myers Scotton, 1993). Thus, a model of bilingual speech must provide control procedures for the local matching of both language systems (Myers Scotton, 1993; Jake 1995; Jake & Myers Scotton 1997).

Recently, MacSwan (1997, 1999) presented a minimalist approach to intrasentential code-switching. He claims that “nothing constrains code switching apart from the requirements of the mixed grammars”, a claim that does not entail a theory about which principles of grammar are relevant to code switching, but “leaves open any and all independently motivated considerations in linguistic theory to the analysis of codeswitching data”.

A theory of a multilingual competence should thus be identical with any linguistic theory in general. Consequently, it can be concluded that a linguistic theory must,

in order to be complete, give a full account of the ways multilingual repertoires can be used to produce mixed utterances. Thus, new research on the bilingual or multilingual lexicon (e.g. de Groot and Nas 1991, Cenoz et al. 2003) must be taken into account by every general theory of the lexicon.

Vice versa, each lexical — and language — theory will have to be judged by its capacity to account for bilingual speech.

3.4 MULTILINGUALISM AND THINKING

Suppose a person can speak and think in two or more than two languages. Does that person think differently in each language? Further, do multilinguals – people who can speak two and possible more languages – think differently from monolinguals – people who can speak only one language? What differences, if any, emanate from the availability of multiple languages versus just one? Might multilingualism affect intelligence, positively or negatively?

Does multilingualism make thinking in any one language more difficult, or does it enhance thought processes? The data are somewhat self-contradictory (Hakuta, 1986). Different participant populations, different methodologies, different language groups, and different experimenter biases may have contributed to the inconsistency in the literature. Consider what happens when bilinguals are balanced bilinguals, who are roughly equally fluent in both languages, and when they come from middle-class backgrounds. In these instances, positive effects of bilingualism tend to be found but negative effects may result under other circumstances.

Let us distinguish between additive versus subtractive bilingualism (Cummins, 1976). As we have studied earlier, a second language is acquired in addition to a relatively well-developed first language in additive bilingualism; whereas, in subtractive bilingualism, elements of a second language replace elements of the first language.

It appears that the additive form results in increased thinking ability. In contrast, the subtractive form results in decreased thinking ability (Cummins, 1976). In particular, there may be something of a threshold effect. Individuals may need to be at a certain relatively high level of competence in both languages for a positive effect of bilingualism to be found.

In a study by Eleanor (1993), the relationships among language proficiency, learning mode, learning style, abstract reasoning, and age of second language acquisition in 227 adults was investigated. The subjects, most of whom were university students, included 17 monolinguals, 120 partial multilinguals, and 90 competent multilinguals.

For comparison with competent multilinguals, the monolinguals and partial multilinguals were grouped together. All were tested for language proficiency, learning style (diverger, assimilator, converger, accommodator), learning mode (concrete experience, reflective observation, abstract conceptualisation, active experimentation), and analogy-solving ability. Native English-speakers had higher analogy-solving scores than native speakers of other languages, regardless of language proficiency; competent multilinguals scored highest.

Among competent multilinguals, native English-speakers scored higher than non-native speakers. Competent multilinguals scored lower on reflective observation than did other subjects. There was also a significant negative correlation between learning mode and analogy-solving ability.

No significant difference was found in learning styles, and no significant interaction effect between language proficiency and learning mode or style on analogy-solving ability. Individuals learning the second language after age 12 had higher analogy-solving scores than those learning it earlier. However, early-second-language-learners were more likely to be competent multilinguals.

3.4.1 Other Benefits

The advantages that multilinguals exhibit over monolinguals are not restricted to linguistic knowledge only, but extend outside the area of language (Cook, 1999, 2002), and the substantial long-lived cognitive, social, personal, academic, and professional benefits of enrichment bilingual contexts have been well documented (Thomas & Collier, 1998).

Children and older persons learning foreign languages have been demonstrated to:

- 1) Have a keener awareness (Galambos & Goldin-Meadow, 1990; Ewert, 2006, 2008) and sharper perception of language (enhanced metalingual abilities, e.g. detection of anomalous sentences; Bialystok, 2001).
- 2) Foreign language learning “enhances children’s understanding of how language itself works and their ability to manipulate language in the service of thinking and problem solving” (Cummins, 1981);
- 3) Be consistently better able to deal with distractions, which may help offset age-related declines in mental dexterity (Bialystok *et al.*, 2004);
- 4) Have a better ear for listening and sharper memories (Ratte, 1968; Lapkin *et al.*, 1990);
- 5) Develop not only better verbal, but also spatial abilities (Diaz, 1983);
- 6) Display generally greater cognitive flexibility, better problem solving and higher-order thinking skills (Hakuta, 1986).
- 7) They have better ‘measures of conceptual development’, ‘creativity’ and ‘analogical reasoning’ (Diaz, 1985), divergent thinking and figural creativity (Landry, 1968, 1972, 1973, 1974).
- 8) Bilinguals or multilinguals are more used to switching thought patterns and have more flexible minds.
- 9) Foreign language learners consistently outperform their peers in core subject areas on standardised tests. For instance, multilingual children in Brussels secondary schools outperform their monoglot schoolmates in problem-solving and fraction exercises;
- 10) They possess extra skills in language use, e.g. engage in transfer, borrowing, insertional, alternational, inter- and intra-sentential code switching (Grosjean, 1989), mixing, and translation patterns that are usual and natural rather than exceptional (as is in the case of monoglots), and analyse as psycholinguistically motivated hybrid utterances serving different interactional, linguistic, pragmatic, cognitive and strategic functions (Majer, 2006).

Thus, just like Latin once used to be taught as an academic exercise, mental gymnastics with the aim of cognitive training, it has been demonstrated that people who know more than one language usually think more flexibly than monolinguals.

3.5 ACQUISITION OF A SECOND LANGUAGE

Languages are learnt at different ages, in different situations and up to very different levels of competence. This has of course consequences for the way multilingual repertoires will be structured. It is thus crucial to analyse the social context in which the different varieties making up a multilingual repertoire have been acquired. Recent research has shown for instance that “passive” exposure to other languages during childhood can lead to an unfocussed form of language learning and to a form of competence that can be reactivated at later stages if necessary (Ellis 1995, Franceschini 1996, 1999).

A significant factor believed to contribute to acquisition of a language is ‘age’. Research has shown that some aspects of a second language, such as vocabulary comprehension and fluency, seem to be acquired just as well after adolescence as before. The mastery of nativelike pronunciation, however, seems to depend on early acquisition. In any case, there do not appear to be critical periods for second-language acquisition (Birdsong, 1999). The possible exception is the acquisition of native accent.

Adults may appear to have a harder time learning second languages because they can retain their native language as their dominant language. Young children, in contrast, who typically need to attend school in the new language, may have to switch dominant language. They thus learn the new language to a higher level of mastery.

It is assumed that learning a (second) language is a series of cognitive procedures by which the learner progressively constructs the grammar of the new language, not only assisted by a “language acquisition device” (more for L1, less for L2), but also with the support from more competent members of the community (Vygotsky 1978) in the compass of a “language acquisition support system” based on social interaction (Bruner 1982, 1983).

Research on second language acquisition has shown the importance of a set of interactive procedures. These may be observed in exolingual situations that provide the non-native speaker the necessary help not only to communicate, but also to continue his/her learning process (e.g. Krafft & Dausendschön-Gay 1994).

What kinds of learning experiences facilitate second-language acquisition? There is no single correct answer to this question (Bialystock & Hakuta, 1994). One reason is that each individual language learner brings distinctive cognitive abilities and knowledge to the language-learning experience. In addition, the kinds of learning experiences that facilitate second-language acquisition should match the context and uses for the second language once it is acquired.

For example, consider four different individuals. Ria, a young child, may not need to master a wealth of vocabulary and complex syntax to get along well with other children. If she can master the phonology, some simple syntactical rules, and some basic vocabulary, she may be considered fluent.

Similarly, Kishen needs only to get by in a few everyday situations, such as shopping, handling routine family business transactions, and getting around town. He may be considered proficient after mastering some simple vocabulary and syntax, as well as some pragmatic knowledge regarding context-appropriate manners of communicating.

Meenakshi must be able to communicate regarding her specialised technical field. She may be considered proficient if she masters the technical vocabulary, a primitive basic vocabulary, and the rudiments of syntax.

Sumesh is a student who studies a second language in an academic setting. Sumesh may be expected to have a firm grasp of syntax and a rather broad, if shallow, vocabulary. Each of these language learners may require different kinds of language experiences to gain the proficiency being sought. Different kinds of experiences may be needed to enhance their competence in the phonology, vocabulary, syntax, and pragmatics of the second language.

When speakers of one language learn other languages, they find the languages differentially difficult. For example, it is much easier, on average, for a native speaker of English to acquire Spanish as a second language than is to acquire Russian. One reason is that English and Spanish share more roots than do English and Russian. Moreover, Russian is much more highly inflected than are English and Spanish. English and Spanish are more highly dependent on word order. The difficulty of learning a language as a second language, however, does not appear to have much to do with its difficulty as a first language. Russian infants probably learn Russian about as easily as U.S. infants learn English.

3.5.1 Single-System Versus Dual-System Hypotheses

One way of approaching multilingualism is to apply what we have learned from cognitive-psychological research to practical concerns regarding how to facilitate acquisition of a new language. Another approach is to study multilingual individuals to see how multilingualism may offer insight into human mind. For example, some cognitive psychologists have been interested in finding out how the different languages are represented in multilingual's mind. The *single-system hypothesis* suggests that two or more languages are represented in just one system or brain region (see Hernandez & associates, 2001, for evidence supporting this hypothesis in early multilinguals).

Alternatively, the *dual-system hypothesis* suggests that two/different languages are represented somehow in separate systems of mind (De Houwer, 1995; Paradis, 1981). For instance, might German language information be stored in a physically different part of the brain than English language information?

One way to address this question is through the study the multilinguals who have experienced brain damage. Suppose a multilingual person has brain damage in a particular part of the brain. An inference consistent with the dual-system hypothesis would be that the individual would show different degrees of impairment in the different languages. The single-system view would suggest roughly equal impairment in all the languages. The logic of this kind of investigation is compelling. But the results were not. When recovery of language after trauma is studied, sometimes the first language recovers first, sometimes the second/latter acquired language recovers first. And sometimes recovery is about equal for all the languages .

In a related situation, an early bilingual aphasic was trained in his native language but was given no training in his second language (Meinzer & associates, 2006). The researchers found significant recovery of the first language but no change in the individual's ability to use the second language.

The conclusions that can be drawn from all this research are equivocal. Nevertheless, the results seem to suggest at least some duality of structure. A different method of study has led to an alternative perspective on multilingualism. Two investigators mapped the region of cerebral cortex relevant to language use in two of their bilingual patients being treated for epilepsy (Ojemann & Whitaker, 1978). Mild electrical stimulation was applied to the cortex of each patient. Electrical stimulation tends to inhibit activity where it is applied. It leads to a reduced activity to name the objects for which the memories are stored at the location being stimulated. The results for both patients were the same.

The results of this study suggest some aspects of the two languages may be represented singly. Other aspects may be represented separately.

3.6 NEURAL MECHANISM OF MULTILINGUALS

The question whether we may speak of one entwined or several separated systems cannot be fully answered alone by the experimental studies discussed above. Neurosciences may offer additional insights. The functional magnetic resonance imaging (fMRI) has been able to throw light on a large number of factors.

Answers to questions like whether there is a difference between balanced and unbalanced bilinguals, Whether there is a, relation between the neuronal network constructed when learning a second language and the 'classical' language centre, whether the first be integrated into the latter and whether.

The research findings in the neuroanatomy of bilinguals are still contradictory and the analysis of cases of bilingual speech used by speakers with different kinds of multilingual competencies could shed new light on these questions.

Early bilinguals seem to build up a network in sufficiently adaptable to allow the integration of later acquired languages. Late bilinguals have to establish new neural areas to guarantee development of their late-acquired languages. These results could have an important impact on the structure of an integrated language theory. Such a theory will consider multilingual repertoires and their use in different contexts the default case, monolingual competencies and monolingual speech representing just one many cases to be explained. It will match new ways of modelling the dynamics of intercultural communication and contribute to it.

3.7 LET US SUM UP

To summarize, different languages seem to share some, but not all, aspects of mental representation. Learning a second language is often a plus, but it is probably most useful if the individual learning the second language is in an environment in which the learning of the second language adds to rather than subtracts from the learning of the first language.

Moreover, for beneficial effects to appear, the second language must be learned well. In the approach usually taken in schools, students may receive as little as 2

or 3 years of second-language instruction spread out over a few class periods a week. This approach probably will not be sufficient for the beneficial effects of bilingualism to appear. However, schooling does seem to yield beneficial effects on acquisition of syntax.

This is particularly so when a second language is acquired after adolescence. Furthermore, individual learners should choose specific kinds of language-acquisition techniques to suit their personal attributes. These attributes include abilities, preferences, and personal goals for using the second language.

3.8 UNIT END QUESTIONS

- 1) Describe the various processes involved in multilingualism?
- 2) Why study of multilingualism is important for cognitive psychologists?
- 3) What can multilingualism tell us about language structures and processes?
- 4) What are the advantages of being bilingual? Can you think of any disadvantages?
- 5) Give a detailed account of language acquisition of a second language.
- 6) Suppose you are an instructor of English as a second language. What kinds of things will you want to know about your students to determine how much to emphasise phonology, vocabulary, syntax, or pragmatics in your instruction?

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UNIT 4 LANGUAGE AND SPEECH DISORDERS

“Language comes so naturally to us that it is easy to forget what a strange and miraculous gift it is.”
– Steven Pinker

Structure

- 4.0 Introduction
- 4.1 Objectives
- 4.2 Defining Language and Speech Disorders
- 4.3 Language Disorders
 - 4.3.1 Aphasia
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- 4.5 Let Us Sum Up
- 4.6 Unit End Questions
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4.0 INTRODUCTION

Communication is so pervasive in any community in its day-to-day activities that it is often taken for granted (Sternberg, 2001). Normal language develops over a period and it is sequential or ordered (Crystal, 1992). A child acquires vocalisation, speech sounds (vowels and consonants) and then prosodies. This acquisition is in recognisable stages that entail acquisition of form, content, and use (Seymour & Nober, 1997). The form is the system of symbols that convey meaning and it is made up of the phonology, morphology, and syntax of a language. The content includes the individual words and combinations of words to produce meaning in the language. Content is made up of the semantics of a language. Use involves how we use words in contexts and is made up of the pragmatics of a language.

Many things could go wrong with the natural order of language acquisition and development. In every community, we encounter individuals with language and/or a speech disorders. One in 10 people in the United States is affected by a communication disorder (speech, language, or hearing disorders). Unfortunately,

there is much ignorance as far as identifying these disorders is concerned. The ignorance more often than not leads to mishandling of the persons with language and speech disorders.

4.1 OBJECTIVES

After reading this unit, you will be able to:

- Define language and speech disorders;
- Explain speech disorders;
- List the causes for speech disorders;
- Enumerate the language disorders; and
- Explain treatment for the speech and language disorders.

4.2 DEFINITION OF LANGUAGE AND SPEECH DISORDERS

Language and speech are said to be disordered or impaired if they differ from what is considered the norm. As already indicated, the yardstick is embedded in the culture of each language; what may be considered disordered in one language will not necessarily be disordered in another language. There is need, therefore, to distinguish between genuine speech disorder and people's cultural tendencies or practices. For example, Kim (1985) notes that Asian Americans favour verbal hesitancy and ambiguity to avoid offence. They also avoid making spontaneous or critical remarks. One should respect such a community's culture and thus the hesitancy should not be confused with a fluency disorder.

The unique nature of the language and speech disorders is that they are not visible since mostly they are not physically manifested, except defects that affect articulation. Most disorders are not evident until a person opens her/his mouth to speak. The disorders, for the same reason, are often not considered a disability, even by the persons who have them.

Language and speech disorders may be due to factors such as physical, mental, or socialisation defects (Crystal, 1988). Though language and speech disorders are classified together they are slightly different from each other. Let's take them one by one:

4.3 LANGUAGE DISORDERS

Language is the rule-based use of speech sounds to communicate (Sternberg, 2000). Language disorders or language impairments involve the processing of linguistic information. Problems that may be experienced can involve grammar (syntax and/or morphology), semantics (meaning), or other aspects of language. Disordered language may be due to a *receptive problem*, that is, a difficulty in understanding speech sounds (involving impaired language comprehension). It can also be due to an *expressive problem*, that is, a difficulty in producing the speech sounds (involving language production), that follow the arbitrary rules of a specific language. A language disorder can also be due to problems in both reception and expression. Examples include specific language impairment and

aphasia, among others. Language disorders can affect both spoken and written language, and can also affect sign language; typically, all forms of language will be impaired.

Note that these are distinct from speech disorders, which involve difficulty with the act of speech production, but not with language. Language disorders, therefore, refer to the following:

The use of speech sounds in combinations and patterns that fail to follow the arbitrary rules of a particular language is a language disorder. For instance, the lack of communication etiquette is considered a language disorder. Talking out of turn, not talking when it is your turn, or not responding when you are expected to could be disorders if frequently observed in one's language behaviour.

The delay in the use of speech sounds relative to normal development in the physical, cognitive, and social areas is another language disorder. Most language disorders are often diagnosed in conjunction with other developmental delays — for instance, health, sensory, motor, mental, emotional, and behavioural development.

Language disorder is a disorder that is found in the development or use of the knowledge of language. It shows the breakdown in the development of language abilities on the usual developmental schedule. The disorders that come under language disorders are: Autism, Learning Disability, Specific Language Impairment, Developmental Phonological Disorders Aphasia, Dyspraxia, etc. We shall discuss the most common language disorders in detail:

4.3.1 Aphasia

Aphasia is an impairment of language functioning caused by damage to the left hemisphere of the brain (Garrett, 2003; Hillis & Caramazza, 2003). There are different type of aphasia, example; Broca's aphasia and Wernicke's aphasia.

Wernicke's aphasia is caused by damage to the left temporal lobe of the brain. It is characterised by notable impairment in the understanding of spoken words and sentences. People with Wernicke's aphasia have generally fluent phonetic and syntactic but semantically coherent speech.

This coherence is exhibited through the creation of nonsense words for real-world concepts and improper substitutions of function words for content words (e.g., nouns, verbs). It also typically involves the production of sentences that have the basic structure of the language spoken but that make no sense. They are sentences without any meaning, e.g. 'Yeah, that was the pumpkin furthest from my thoughts' and 'the scroolish prastimer ate my spanstakes' (Hillis & Caramazza, 2003).

In the first case, the words make sense, but not in the context they are presented. In the second case, the words themselves are neologisms, or newly created words. Treatment for patients with this type of aphasia frequently involves supporting and encouraging nonlanguage communication (Altschuler et al., 2006).

Broca's aphasia is caused by damage to the brain's premotor area, responsible, in part, for controlling motor commands used in speech production. A person suffering from Broca's aphasia exhibits speech containing excess pauses and

slips of tongue, and s/he has trouble finding words when talking. The person also fails to make use of function words such as *a*, *the*, and *of*. For this reason, Broca's aphasics also produce ungrammatical sentences (Tartter, 1987). Furthermore they have problem using syntactic information when understanding sentences (Just & Carpenter, 1987). For example, while a Broca's aphasic has no trouble understanding a sentence such as "The bicycle that the man is holding is blue", but s/he has trouble comprehending a sentence such as "the dog that the woman is biting is grey."

This difference is due to the fact that while the first sentence can be understood using real-world knowledge (e.g. bicycle, not people, are blue), the second sentence cannot (because it is unlikely that a woman would bite a dog). Because understanding the second sentence requires correctly using syntactic information, which Broca's aphasics have difficulty doing, the sentence poses problem for them (Berndt & Caramazza, 1980).

Broca's aphasia differs from Wernicke's aphasia in two key aspects. First is that speech is agrammatical rather than grammatical, as in Wernicke's. Second is that verbal comprehension is largely preserved.

Diseases like Broca's and Wernicke's aphasia, while tragic, tell us much about the critical functions of certain regions of the brain. Notably, their symptoms suggest that (at least certain) phonological, syntactic, and semantic, language information is stored and processed separately in the brain.

Global aphasia is the combination of highly impaired comprehension and production of speech. It is caused by lesions to both Broca's and Wernicke's areas. Aphasia following a stroke frequently involves damage to both Broca's and Wernicke's areas. In one study, researchers found 32 % of aphasias immediately following a stroke in Broca's and Wernicke's areas (Pedersen, Vinter, & Olsen, 2004).

Anomic aphasia involves difficulties in naming objects in retrieving words. The patient may look at an object and simply be unable to retrieve the word that corresponds to the object. Sometimes, specific categories of things cannot be recalled, such as names of living things (Warrington & Shallice, 1984).

4.3.2 Autism

Autism is a developmental disorder characterised by abnormalities in social behaviour, language, and cognition (Jarrold & Happe', 2003). It is biological in its origins, although the genes responsible for it have not been conclusively identified (Lamb et al., 2000). Children with autism are identified by around 14 months of age, when they fail to show expected normal patterns of interaction with others. They display repetitive movements and stereotyped patterns of interests and activities. When they interact with someone, they are more likely to view their lips than their eyes. About half of children with autism fail to develop functional speech. The speech they tend to develop is characterised by echolalia, meaning they repeat, over and over again, speech they have heard. Sometimes the repetition occurs several hours after the original use of the words by someone else.

Children with autism show abnormalities in many areas of the brain, including the frontal and parietal lobes, as well as the cerebellum, brainstem, corpus

callosum, basal ganglia, amygdala, and hippocampus. The disease was first identified in the middle of the twentieth century (Kanner, 1943). It is five times more common in males than females. The incidence of diagnosed autism has increased rapidly over recent years (Chen et al., 2007). Autism is diagnosed today in approximately 60 out of every 10,000 children (Fombonne, 2003). The increase in recent times may be a result of a number of causes, including changes in diagnosing strategies or environmental pollution (Jick & Kaye, 2003; Windham et al., 2006).

4.3.3 Learning Disability

Language-based learning disabilities are problems with age-appropriate reading, spelling, and/or writing. Most people diagnosed with learning disabilities have average to superior intelligence. . In *language-based learning disability* (or just *learning disabilities*), many children with reading problems have spoken language problems. *Dyslexia* has been used to refer to the specific learning problem of reading.

Dyslexia — Dyslexia has been around for a long time and has been defined in different ways. For example, in 1968, the World Federation of Neurologists defined dyslexia as “a disorder in children who, despite conventional classroom experience, fail to attain the language skills of reading, writing, and spelling commensurate with their intellectual abilities.” Dyslexia is not due to mental retardation, brain damage, or a lack of intelligence. It is caused by an impairment in the brain’s ability to translate images received from the eyes or ears into understandable language. The severity of dyslexia can vary from mild to severe. It is found more often in boys than in girls. The sooner dyslexia is treated, the more favorable the outcome; however, it is never too late for people with dyslexia to learn to improve their language skills (Schulte-Körne, Warnke, & Remschmidt, 2006).

Letter and number reversals are the most common warning sign of dyslexia (Birsh, 2005). Difficulty in copying from the board or a book can also suggest problems. The child may appear to be uncoordinated and have difficulty with organised sports or games. Difficulty with left and right is common, and often dominance for either hand has not been established. Auditory problems in dyslexia encompass a variety of functions. Commonly, a child may have difficulty remembering or understanding what he hears. Parts of words or parts of whole sentences may be missed, and words can come out sounding funny. Children struggling with this problem may know what they want to say but have trouble finding the actual words to express their thoughts (Sperling et al., 2006).

There are several types of dyslexia that can affect the child’s ability to spell as well as read (Heim, Tschierse, & Amunts, 2008). *Primary dyslexia* is a dysfunction of, rather than damage to, the left side of the brain (cerebral cortex) and does not change with age. Individuals with this type are rarely able to read above a fourth-grade level and may struggle with reading, spelling, and writing as adults. Primary dyslexia is passed in family lines through their genes (hereditary). *Secondary or developmental dyslexia* and is felt to be caused by hormonal development during the early stages of fetal development. Developmental dyslexia diminishes as the child matures (Galaburda & Cestnick, 2003).

Dyslexia may affect several different functions. *Visual dyslexia* is characterised by number and letter reversals and the inability to write symbols in the correct sequence. *Auditory dyslexia* involves difficulty with sounds of letters or groups of letters. The sounds are perceived as jumbled or not heard correctly. *Dysgraphia* refers to the child's difficulty holding and controlling a pencil so that the correct markings can be made on the paper (Facoetti et al., 2003).

Many subtle signs can be observed in children with dyslexia. Due to the frustration arising from the difficulty in reading, children may become withdrawn and may show signs of depression and low self-esteem. Peer and sibling interactions can become strained. The child may become unmotivated and develop a dislike for school. The child's success in school may be jeopardised if the problem remains untreated.

4.3.4 Alzheimer's Disease

Alzheimer's disease is a brain disorder which leads to a decrement in language processing ability. This disease primarily afflicts elderly persons and causes progressive, diffused, and irreversible damage to the cortical regions of the brain, impacting markedly on memory functions. Comparison between the language decrements due to the dementing effects of Alzheimer's disease and those noted for the aphasics is useful because the average age of onset of Alzheimer's Disease overlaps that of aphasias (around 50 to 60 years of age).

The language of an Alzheimer's patient is marked by a striking simplification process wherein words that once precisely described some event are now lost and are replaced by more general terms because of a fundamental loss of categorical organisation in semantic memory (Chan et al., 1993; Martin & Fedio, 1983). It appears, however, that in patients suffering from Alzheimer's disease, phonological and syntactic knowledge and use is minimally affected. Finally, a deficit in pragmatic knowledge, concerning the correct recognition of the intention of a speech act (e.g., that an utterance is meant to be taken as a request), turntaking in a conversation, and so on also occurs. Interestingly, this pattern of deficits and nondeficits again argues for the distinctiveness of the various levels of language information similar to what was seen for Broca's and Wernicke's aphasias (Bayles & Kaszniak, 1987).

4.3.5 Specific Language Impairment

Specific language impairment (SLI) is a developmental language disorder in the absence of frank neurological, sensorimotor, nonverbal cognitive or social emotional deficits (see Watkins, 1994). SLI is used to refer to problems in the acquisition and use of language, typically in the context of normal development. Children with SLI lag behind their peers in language production and language comprehension, which contributes to learning and reading disabilities in school.

One of the hallmarks of SLI is a delay or deficit in the use of function morphemes (e.g., *the*, *a*, *is*) and other grammatical morphology (e.g., plural -s, past tense -ed). Individuals with SLI exhibit problems in combining and selecting speech sounds of language into meaningful units (phonological awareness).

These problems are different to speech impairments that arise from difficulties in coordination of oral-motor musculature (Cohen, 2002). Symptoms include

the use of short sentences, and problems producing and understanding syntactically complex sentences. SLI is also associated with an impoverished vocabulary, word finding problems, and difficulty learning new words, whereas the basic tasks for development of phonology and syntax are completed in childhood, vocabulary continues to grow in adulthood (Bishop, 1997).

Some researchers claim that SLI children's difficulty with grammatical morphology is due to delays or difficulty in acquiring a specific underlying linguistic mechanism. For example, difficulty in acquiring the rule that verbs must be marked for tense and number ("he walks", not "he walk") (Rice & Wexler, 1994).

These children have a deficit in processing brief and/or rapidly changing auditory information, and/or in remembering the temporal order of auditory information (Tallal, et al., 1985). Children with SLI have poor short-term memory for speech sounds (example, Gathercole, 1998). In a number of recent studies short-term memory for speech sounds has been shown to correlate highly with vocabulary acquisition and speech production. This has led to the hypothesis that a primary function of this memory is to facilitate language learning.

Moreover, among SLI children, about 50% will go on to experience reading difficulties and develop dyslexia (Bishop & Snowling, 2004).

4.3.6 Developmental Phonological Disorders

"Developmental Phonological Disorders, also known as phonological disability or phonological disorders, are a group of language disorders that affect children's ability to develop easily understood speech by the time they are four years old, and, in some cases, their ability to learn to read and spell. Therefore, Phonological disorders involve a difficulty in learning and organising all the sounds needed for clear speech, reading and spelling" (Bowen, 1998).

Individuals with this Communication Disorder of childhood demonstrate impairment in their ability to produce sounds as expected for their developmental level. Some children with developmental phonological disorders have other speech and language difficulties such as immature grammar and syntax, stuttering or word-retrieval difficulties.

The cause of phonological disorder in children is largely unknown. It has been suggested that this disorder has a genetic component due to the large proportion of children who have relatives with some type of similar disorder. However there is no available data to support these observations. Developmental phonological disorders may occur in conjunction with other communication disorders such as stuttering, specific language impairment (SLI), or developmental apraxia of speech. No matter what combination of difficulties a child with a developmental phonological disorder has, appropriate speech-language pathology treatment is usually successful in eliminating or at the very least, reducing the problem (Bowen, 1998).

4.3.7 Dyspraxia

Developmental dyspraxia is a disorder characterised by impairment in the ability to plan and carry out sensory and motor tasks (Dewey, 1995). Generally, individuals with the disorder appear "out of sync" with their environment.

Symptoms vary and may include poor balance and coordination, clumsiness, vision problems, perception difficulties, emotional and behavioural problems, difficulty with reading, writing, and speaking, poor social skills, poor posture, and poor short-term memory. Although individuals with the disorder may be of average or above average intelligence, they may behave immaturely (Henderson & Henderson, 2003).

Developmental dyspraxia is a lifelong disorder. Many individuals are able to compensate for their disabilities through occupational and speech therapy. Treatment is symptomatic and supportive and may include occupational and speech therapy, and “cueing” or other forms of communication such as using pictures and hand gestures. Many children with the disorder require special education (Alloway & Temple, 2007).

4.4 SPEECH DISORDERS

Speech disorders are characterised by a difficulty in producing normal speech patterns. Children go through many stages of speech production while they are learning to communicate. What is normal in the speech of a child of one age may be a sign of a problem in an older child. Speech is the vocal utterance of language and it is considered disordered in three underlying ways: voice, articulation, and fluency (Roseberry-McKibbin, 1995).

These disorders include *voice disorders* (abnormalities in pitch, volume, vocal quality, resonance, or duration of sounds), *speed sound disorders/articulation disorders* (problems producing speech sounds), and *fluency disorders* (impairment in the normal rate or rhythm of speech, such as stuttering).

4.4.1 Voice Disorders

Voice involves the coordinated effects of the lungs, larynx, vocal chords, and nasal passage to produce recognisable sounds. Voice can thus be considered disordered if it is incorrectly phonated or if it is incorrectly resonated. In the incorrect phonation an individual could have a breathy, strained, husky, or hoarse voice. With the incorrect resonance an individual could have hyper-nasality or hypo-nasality. The voice disorders could also be due to improper voicing habits.

Paralanguage issues, such as use of pitch, volume, and intonation, are diverse for they are culturally determined. Every sound of voice has a possible range of meanings that could be conveyed simply through the voice rather than the words we use. The features that should be considered in determining a voice disorder are:

Volume: how loudly or softly we speak

Pitch: how pleasant or unpleasant

Quality: the highness or lowness of one's voice

Rate: the speed at which one speaks

Voice disorders are interpreted variously in different cultures. For instance, in many African cultures masculinity and femininity are determined by paralinguistic features. A man who speaks in a low volume, a high pitch, or a smooth and slow voice, would be frowned upon and called upon to “speak like a man.”

4.4.2 Speech Sound Disorders

These involve difficulty in producing specific speech sounds (most often certain consonants, such as /s/ or /r/), and are subdivided into articulation disorders (also called phonetic disorders) and phonemic disorders. Articulation disorders are characterised by difficulty learning to physically produce sounds.

Phonemic disorders are characterised by difficulty in learning the sound distinctions of a language, so that one sound may be used in place of many. However, it is not uncommon for a single person to have a mixed speech sound disorder with both phonemic and phonetic components.

- i) **Articulation disorders:** Articulation involves the use of the tongue, lips, teeth and mouth to produce recognisable speech sounds. Articulation is disordered if sounds are added, omitted, substituted or distorted. Articulation disorders may be caused by factors such as structural abnormalities, for example, a cleft lip and/or palate, a tongue-tie, missing teeth, a heavy tongue, or a deformed mouth; faulty or incomplete learning of the sound system; or damage of the nervous system.

Apart from affecting articulation, such conditions also affect the self-concept of the persons (Leonard et al., 1991). For instance, Pinky Sonkar, an eight-year-old girl from Mirzapur in Uttar Pradesh, (On her life the documentary *Smile Pinky* was made by American filmmaker Magan Mylan, which won Oscars for Best Documentary), had stopped smiling, even stopped going to school because she was ashamed of her cleft lip, a deformity 35,000 children are born with in India every year. Then in 2008, The Smile Train arrived in Pinky's village and a seemingly routine plastic surgery was offered free by doctors' abroad and her world was changed forever.

- ii) **Phonemic disorders:** are speech disorders in which individuals have trouble physically producing certain sounds. In the general population phonemic disorders are sometimes called speech impediments. Usually individuals with phonemic disorders have trouble distinguishing the sounds made by certain letters so that some letters, for example all "t"s or all "c"s, are always pronounced with an incorrect sound as a substitution. Phonemic disorders usually improve with speech therapy, though how much improvement may be made will depend upon each individual case.

4.4.3 Fluency Disorders

Fluency involves appropriate pauses and hesitations to keep speech sounds recognisable. Fluency is disordered if sounds are very rapid with extra sounds (cluttered), if sounds are repeated or blocked especially at the beginnings of words (stuttered), or if words are repeated.

Fluency disorders are more prevalent in children and they are due to a combination of familial, psychological, neurological, and motoric factors.

The social nature of communication is affected when one has disfluent speech. Human beings are social and they spend much of their time together. They first learn how to communicate in a social set up — for instance, with parents, siblings, relations, or friends. Socialisation is adversely affected if one has a fluency speech disorder. A person with disfluency is often mishandled at home, in school, or in public place. Often the individual becomes withdrawn.

4.4.4 Apraxia of Speech

Apraxia of speech, also known as verbal apraxia or dyspraxia, is a speech disorder in which a person has trouble saying what he or she wants to say correctly and consistently. The severity of apraxia of speech can range from mild to severe.

There are two main types of speech apraxia: *acquired apraxia* of speech and *developmental apraxia* of speech. Acquired apraxia of speech can affect a person at any age, although it most typically occurs in adults. It is caused by damage to the parts of the brain that are involved in speaking, and involves the loss or impairment of existing speech abilities. The disorder may result from a stroke, head injury, tumor, or other illness affecting the brain. Acquired apraxia of speech may occur together with muscle weakness affecting speech production (dysarthria) or language difficulties caused by damage to the nervous system (aphasia) (Epstein, Perkin, Cookson, & de Bono, 2003).

Developmental apraxia of speech (DAS) occurs in children and is present from birth. It appears to affect more boys than girls. This speech disorder goes by several other names, including developmental verbal apraxia, developmental verbal dyspraxia, articulatory apraxia, and childhood apraxia of speech. DAS is different from what is known as a developmental delay of speech, in which a child follows the “typical” path of speech development but does so more slowly than normal. The causes of DAS are not yet known. Some scientists believe that DAS is a disorder related to a child’s overall language development.

Others believe it is a neurological disorder that affects the brain’s ability to send the proper signals to move the muscles involved in speech. However, brain imaging and other studies have not found evidence of specific brain lesions or differences in brain structure in children with DAS. Children with DAS often have family members who have a history of communication disorders or learning disabilities. This observation and recent research findings suggest that genetic factors may play a role in the disorder (Kasper et al., 2005).

People with either form of apraxia of speech may have difficulty putting sounds and syllables together in the correct order to form words. They also tend to make inconsistent mistakes when speaking. For example, they may say a difficult word correctly but then have trouble repeating it, or they may be able to say a particular sound one day and have trouble with the same sound the next day. They often appear to be groping for the right sound or word, and may try saying a word several times before they say it correctly. Another common characteristic of apraxia of speech is the incorrect use of “prosody” — that is, the varying rhythms, stresses, and inflections of speech that are used to help express meaning. The severity of both acquired and developmental apraxia of speech varies from person to person. It can range from so mild having trouble with very few speech sounds to the severe cases of being not able to communicate effectively.

4.4.5 Dysprosody

Dysprosody is the rarest neurological speech disorder. It is characterised by alterations in intensity, in the timing of utterance segments, and in rhythm, cadence, and intonation of words. The changes to the duration, the fundamental frequency, and the intensity of tonic and atonic syllables of the sentences spoken, deprive an individual’s particular speech of its characteristics. The cause of

dysprosody is usually associated with neurological pathologies such as brain vascular accidents, cranioencephalic traumatism, and brain tumors (Pinto, Corso, Guilherme, Pinho, & Nobrega, 2004).

4.4.6 Dysarthria

Dysarthria is a motor speech disorder. It is a weakness or paralysis of speech muscles caused by damage to the nerves and/or brain. The type and severity of dysarthria depend on which area of the nervous system is affected. Dysarthria is often caused by strokes, Parkinson's disease, Amyotrophic lateral sclerosis (ALS), head or neck injuries, surgical accident, or cerebral palsy.

A person with dysarthria may experience any of the following symptoms, depending on the extent and location of damage to the nervous system: "slurred" speech, speaking softly or barely able to whisper, slow rate of speech, rapid rate of speech with a "mumbling" quality, limited tongue, lip, and jaw movement, abnormal intonation (rhythm) when speaking, changes in vocal quality ("nasal" speech or sounding "stuffy"), hoarseness, breathiness, drooling or poor control of saliva, chewing and swallowing difficulty etc.

A speech-language pathologist (SLP) can evaluate a person with speech difficulties and determine the nature and severity of the problem. The SLP will look at movement of the lips, tongue, and face, as well as breath support for speech, voice quality, and more.

Children with isolated speech disorders are often helped by articulation therapy, in which they practice repeating specific sounds, words, phrases, and sentences. For stuttering and other fluency disorders, a popular treatment method is fluency training, which develops coordination between speech and breathing, slows down the rate of speech, and develops the ability to prolong syllables. Delayed auditory feedback (DAF), in which stutterers hear an echo of their own speech sounds, has also been effective in treating stuttering.

When a speech problem is caused by serious or multiple disabilities, a neurodevelopmental approach, which inhibits certain reflexes to promote normal movement, is often preferred. Other techniques used in speech therapy include the motor-kinesthetic approach and biofeedback, which helps children know whether the sounds they are producing are faulty or correct. For children with severe communication disorders, speech pathologists can assist with alternate means of communication, such as manual signing and computer-synthesised speech.

4.5 LET US SUM UP

In this unit we have defined both speech and language disorders. We have also indicated the various causative factors leading to these disorders. Language is the rule-based use of speech sounds to communicate (Sternberg, 2000). Language disorders or language impairments involve the processing of linguistic information. Problems that may be experienced can involve grammar (syntax and/or morphology), semantics (meaning), or other aspects of language. Disordered language may be due to a *receptive problem*, that is, a difficulty in understanding speech sounds (involving impaired language comprehension).

It can also be due to an *expressive problem*, that is, a difficulty in producing the speech sounds (involving language production), that follow the arbitrary rules of a specific language. A language disorder can also be due to problems in both reception and expression. Examples include specific language impairment and aphasia, among others. Language disorders can affect both spoken and written language, and can also affect sign language; typically, all forms of language will be impaired.

Note that these are distinct from speech disorders, which involve difficulty with the act of speech production, but not with language. Language disorders, therefore, refer to the following:

The use of speech sounds in combinations and patterns that fail to follow the arbitrary rules of a particular language is a language disorder. For instance, the lack of communication etiquette is considered a language disorder. Talking out of turn, not talking when it is your turn, or not responding when you are expected to could be disorders if frequently observed in one's language behaviour.

Language disorder is a disorder that is found in the development or use of the knowledge of language. It shows the breakdown in the development of language abilities on the usual developmental schedule. The disorders that come under language disorders are: Autism, Learning Disability, Specific Language Impairment, Developmental Phonological Disorders include Aphasia, Dyspraxia, etc.

Aphasia is an impairment of language functioning caused by damage to the left hemisphere of the brain (Garrett, 2003; Hillis & Caramazza, 2003). There are different type of aphasias, example; Broca's aphasia and Wernicke's aphasia.

Autism is a developmental disorder characterised by abnormalities in social behaviour, language, and cognition (Jarrold & Happe', 2003). It is biological in its origins, although the genes responsible for it have not been conclusively identified (Lamb et al., 2000). Children with autism are identified by around 14 months of age, when they fail to show expected normal patterns of interaction with others. They display repetitive movements and stereotyped patterns of interests and activities. When they interact with someone, they are more likely to view their lips than their eyes. About half of children with autism fail to develop functional speech. The speech they tend to develop is characterised by echolalia, meaning they repeat, over and over again, speech they have heard. Sometimes the repetition occurs several hours after the original use of the words by someone else .

Language-based learning disabilities are problems with age-appropriate reading, spelling, and/or writing. Most people diagnosed with learning disabilities have average to superior intelligence. . In *language-based learning disability* (or just *learning disabilities*), many children with reading problems have spoken language problems. *Dyslexia* has been used to refer to the specific learning problem of reading.

Alzheimer's disease is a brain disorder which leads to a decrement in language processing ability. This disease primarily afflicts elderly persons and causes progressive, diffused, and irreversible damage to the cortical regions of the brain, impacting markedly on memory functions. Comparison between the language

decrements due to the dementing effects of Alzheimer's disease and those noted for the aphasics is useful because the average age of onset of Alzheimer's Disease overlaps that of aphasia (around 50 to 60 years of age).

The language of an Alzheimer's patient is marked by a striking simplification process wherein words that once precisely described some event are now lost and are replaced by more general terms because of a fundamental loss of categorical organisation in semantic memory .

Specific language impairment (SLI) is a developmental language disorder in the absence of frank neurological, sensorimotor, nonverbal cognitive or social emotional deficits (see Watkins, 1994).

Moreover, among SLI children, about 50% will go on to experience reading difficulties and develop dyslexia (Bishop & Snowling, 2004).

“Developmental Phonological Disorders, also known as phonological disability or phonological disorders, are a group of language disorders that affect children's ability to develop easily understood speech by the time they are four years old, and, in some cases, their ability to learn to read and spell. Therefore, Phonological disorders involve a difficulty in learning and organising all the sounds needed for clear speech, reading and spelling” (Bowen, 1998).

Developmental dyspraxia is a lifelong disorder characterised by impairment in the ability to plan and carry out sensory and motor tasks (Dewey, 1995). Generally, individuals with the disorder appear “out of sync” with their environment. Symptoms vary and may include poor balance and coordination, clumsiness, vision problems, perception difficulties, emotional and behavioural problems, difficulty with reading, writing, and speaking, poor social skills, poor posture, and poor short-term memory.

Speech disorders are characterised by a difficulty in producing normal speech patterns. Children go through many stages of speech production while they are learning to communicate. What is normal in the speech of a child of one age may be a sign of a problem in an older child. Speech is the vocal utterance of language and it is considered disordered in three underlying ways: voice, articulation, and fluency (Roseberry-McKibbin, 1995).

These disorders include *voice disorders* (abnormalities in pitch, volume, vocal quality, resonance, or duration of sounds), *speed sound disorders/articulation disorders* (problems producing speech sounds), and *fluency disorders* (impairment in the normal rate or rhythm of speech, such as stuttering).

4.6 UNIT END QUESTIONS

- 1) Compare and contrast the speech errors made by individuals in different speech disorders.
- 2) Based on the discussion of language disorders in this chapter, make a worksheet of different kinds of language disorders and their symptoms and causes.
- 3) What do brain disorders like Broca's and Wernicke's aphasia tell us about how a healthy brain processes phonological, syntactic and semantic information?

- 4) Speech disorders have a negative effect on the personality and overall development of the children. Explain with examples, how?
- 5) What are several major features of speech sound disorder?

4.7 SUGGESTED READINGS AND REFERENCES

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UNIT 1 NATURE OF PROBLEM SOLVING

Structure

- 1.0 Introduction
- 1.1 Objectives
- 1.2 Types of Problems
- 1.3 Characteristics of Difficult Problems
- 1.4 Nature of Problem Solving
 - 1.4.1 The Stages of Problem Solving
- 1.5 Types of Thinking Involved in Problem Solving
 - 1.5.1 The Kinds of Thinking Processes
- 1.6 Concept of Insight Problems
- 1.7 Let Us Sum Up
- 1.8 Unit End Questions
- 1.9 Suggested Readings

Problem Solving

“Solving a problem means finding a way out of a difficulty, a way around an obstacle, attaining an aim that was not immediately understandable. Solving problem is the specific achievement of intelligence and intelligence is the specific gift of mankind. Solving problems can be regarded as the most characteristically human activity.”

George Polya (1962)

1.0 INTRODUCTION

In our day to day life we usually solve problems be it the classroom, family, or workplace. It is nearly inescapable in everyday life. We use problem solving when we want to reach a certain goal, and that goal is not readily available. It involves situations in which something is blocking our successful completion of a task. To study problem solving satisfactorily, a good way will be to start the chapter by solving some problems. Give these ones a try:

Problem1: What one mathematical symbol can you place between 2 and 3 that result in a number greater than 2 and less than 3?

Problem2: Rearrange the letters NEWDOOR to make one word.

Problem3: How many pets do you have if all of them are birds except two , all of them are cats except two, all of them are dogs except two.

There are many different kinds of problems, including many kinds of recreational problems, career and school oriented problems (such as the problem of how to get promoted or the problem of how to study for a test), personal problems (such as the problem of who to marry or whether to have a child), and scientific problems (such as how to find a cure for cancer or how to prove a particular theorem) etc.

We all solve many problems like these or others every day. Problem solving can be as commonplace as finding out how to prepare a meal or as significant as developing a psychological test.

1.1 OBJECTIVES

After completing this unit, you will be able to :

- Define the basic nature of problem solving;
- Enlist the different kinds of problems;
- Describe types of thinking involved in problem solving; and
- Analyse and explain the Insight Problem Solving.

1.2 TYPES OF PROBLEMS

Problems vary from ill defined to well defined. In a well defined problem such as a mathematical equation or a jigsaw puzzle both the nature of the problem and the information needed to solve it are available and clear. Thus, one can make straightforward judgments about whether a potential solution is appropriate. With an ill defined problem, such as how to bring peace, not only may the specific nature of the problem be unclear, the information required to solve the problem may be even less obvious.

Greeno (1978) suggested one method of classifying well defined problems based on the general kinds of psychological skills and knowledge needed to solve different problems. Typically, well defined problems falls into one of the three categories viz., (i) Arrangement (ii) Inducing Structure and (iii) Transformation.

Solving each of these types of problems requires somewhat different type of psychological skills and knowledge.

- i) Arrangement of problems requires that the problem solver must rearrange or recombine elements in a way that will satisfy a certain criteria. Usually, several different arrangements can be made but only one or few arrangements will produce a solution. For example, one can say that Anagram problems and jigsaw puzzles are examples of arrangement problems.
- ii) In Problems of inducing Structure, a person must identify the existing relationships among the elements presented. He then should construct a new relationship among them, so that the problem could be solved. In such a problem, the problem solver must determine not only the relationships among the structures but also the structure and size of elements involved.
- iii) In Transformation Problems, one takes into consideration. An attempt is made to change the initial state to a goal state. The Tower of Hanoi is an example of this kind of problem where the initial state is the original configuration, the goal state is to have the three disks on the third peg, and the method is the rules for moving the disks. According to *Greeno* 1978 solving transformation problems primarily requires skills in planning based on a method called means end analysis. Means end analysis requires identifying differences that exist between the current state and the goal state and selecting operations that will reduce these differences.

1.3 CHARACTERISTICS OF DIFFICULT PROBLEMS

Some of the typical characteristics of difficult problems are as given below:

- Intransparency (lack of clarity of the situation)
- Commencement opacity. (confusion regarding how to start stating the problem)
- Continuation opacity (Continuing confusion in regard to the problem as there is no clarity)
- Polytely (The problem has multiple goals and so reaching and selecting a particular goal is difficult)
- Inexpressiveness (inability to express the problem clearly)
- Opposition
- Transience (the problem keeps changing)
- Complexity (The problem is in large numbers of items, too many interrelationships and decisions)
- Enumerability (It is not possible to list it or quantify it)
- Connectivity (There are hierarchy of problems in relation to relationship, communication and allocation)
- Heterogeneity (The problem is not homogeneous and so difficult to handle)
- Dynamics (time considerations)
- Temporal constraints (There is limitation to time factor as it has to be got done within a time period)
- Temporal sensitivity (The problem is influenced and affected by time factor)
- Phase effects (There are changes in different phases of the problem and these affect the problem from being solved)
- Dynamic unpredictability (The problem is complex and consists of high degree of unpredictability)

The resolution of difficult problems requires a direct attack on each of the above mentioned characteristics encountered.

In reform mathematics, greater emphasis is placed on problem solving relative to basic skills, where basic operations can be done with calculators. However some “problems” may actually have standard solutions taught in higher grades, like for instance multiplying rather than adding. For example, kindergarteners could be asked how many fingers are there on all the gloves of 3 children. Normally they will add the fingers in each glove of the three children and say 15. But at a higher level $5 \times 3 = 15$, which is done quickly and solved by applying multiplication.

Self Assessment Questions

1) Define problems

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2) Define problem solving

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3) What are the different types of problems?

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4) What is meant by difficult problems?

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5) What are the characteristics of difficult problems.?

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1.4 NATURE OF PROBLEM SOLVING

The nature of human problem solving methods has been studied by psychologists over the past hundred years. There are several methods of studying problem solving, including introspection, behaviourism, simulation, computer modeling and experiment.

Beginning with the early experimental work of the Gestaltists in Germany and continuing through the 1960s and early 1970s, research on problem solving was typically conducted in relatively simple, laboratory tasks that appeared novel to participants (e.g. Mayer, 1992). In these tasks, they had clearly defined optimal solutions which were solvable within a relatively short time frame, and researchers could trace participants' problem-solving steps, and so on.

The researchers made the underlying assumption that simple tasks such as the Tower of Hanoi captured the main properties of "real world" problems, and that the cognitive processes underlying participants' attempts to solve simple problems were representative of the processes engaged in when solving "real world" problems. Thus researchers used simple problems for reasons of convenience.

Simple laboratory based tasks can be useful in explicating the steps of logic and reasoning that underlie problem solving. However, they omit the complexity and emotional valence of "real-world" problems. In clinical psychology, researchers have focused on the role of emotions in problem solving, demonstrating that poor emotional control can disrupt focus on the target task and impede problem resolution (Rath, Langenbahn, Simon, Sherr, & Diller, 2004).

Human problem solving consists of two related processes, viz., (i) problem orientation, and (ii) problem-solving skills which, if While problem orientation deals with the motivational/attitudinal/affective approach to problematic situations, the problem solving skills deal with the actual cognitive behavioural steps. If cognitive skills are successfully implemented, it will lead to effective problem resolution.

Problem solving is a mental process and is part of the larger problem process that includes problem finding and problem shaping. Considered the most complex of all intellectual functions, problem solving has been defined as higher-order cognitive process that requires the modulation and control of more routine or fundamental skills.

Problem solving occurs when an organism or an artificial intelligence system needs to move from a given state to a desired goal state. Problem solving is one of the many forms that thinking or cognition may take.

By cognition one refers to the mental representation of information which can be manipulated and used to solve problems. Problem solving is a major cognitive behaviour.

Problem solving becomes necessary when an individual wants to reach a goal but that goal is not easily available. It is a state in which there are some obstacles to reach the goal. Various psychologists have defined problem solving.

According to *Baron* (2001) problem solving involves efforts to develop or choose among various responses in order to attain desired goals.

Witting and Williams III (1984) defined problem solving as the use of thought processes to overcome obstacles and work towards goals.

1.4.1 The Stages of Problem Solving

The situation that prevails at the beginning of the problem solving task is the initial state. The system then moves through a series of different, intermediate states, designed to lead to the goal. When the goal is achieved, the system is said to have attained the goal state. Thus there are four molar components of any problem solving activity and these are given below:

- The initial state: How the starting conditions are defined
- The Operators: Moves or operations to move from one state to another
- Intermediate Problem States: Any states that are generated by applying an operator to a state on the way to final goal.
- The goal state: How the final state or goal conditions are described.

The internal representation (or mental model) of these four states of a problem is called “Problem Space”. This problem space varies from one individual to another. It must be kept in mind that each individual’s problem space is unique and depends also on the nature of the problem. The initial state of a problem is critical to problem solving and some problem’s initial state may lead to efficient problem solving while another may end up in high complexity.

Problem solving strategies	Creative problem solving
Group problem solving	Problem solving approach
Management problems solving	Elementary problem solving
Problem solving activities	Problem solving worksheets
Teaching problem solving	Problem solving lesson plans
Problem solving skills	
Art Problem solving	

Self Assessment Questions

- 1) Describe the nature of problem solving.

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- 2) What are real world problems? Give suitable examples.

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3) What are the two processes in human problem solving.

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4) Describe the stages of problem solving.

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5) What are the four molar components of any problem solving activities?

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6) What is meant by “Problem Space”?

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1.5 TYPES OF THINKING INVOLVED IN PROBLEM SOLVING

According to Wertheimer (1959) effective problem solving requires:

- i) Productive thinking
- ii) Being sensitive and open to structural requirements
- iii) Going beyond the knowledge learnt from previous problem solving tasks

For productive thinking there is a need to have a grasp of the general principles that apply in the particular problem situation. Since individuals do have a tendency to reproduce thinking appropriate for other situations, they need to think beyond

that solution and look for unique solutions. It is important to keep in mind the structure of the problem without which solutions may not come about.

1.5.1 The Kinds of Thinking Processes

The kinds of thinking processes involved in problem solving are:

- 1) Analytical Thinking
- 2) Synthetic Thinking.

In analytic thinking, there is nothing more in solution than in the premise. For example if the problem is a simple question like “how many doors are there in your house”, then the answer is simple counting of the doors and adding it up. There can be no other answer and there can also be no other solution.

In contrast, Synthetic Thinking does not contain the conclusion in the premise itself because the solution is not needed in the construction of the mental object. For example, we know that 2 is a divisor of 4, 4 is a divisor of 8, and 2 is also a divisor of 8. In general, it is true that a divisor of a divisor of a number is a divisor of that number.

Such solutions are best reached by constructing mental model like images like number lines.

The importance of synthetic thinking is that you can get out more than you put into it.

After you construct a mental model, you can see relationships that were not evident before you constructed it. Seeing these new relationships is what comprises problem solving through synthetic thinking.

In other words, one is synthesizing the available information and facts to derive new solution. This is also termed as developing insight.

Newell is one of the most influential cognitive psychologists who made computer stimulation approach to the study of problem solving.

Newell stated that the goal is to construct a mental model. From this model one will find answers to a problem by inspecting that model itself. To do this, one writes parts of the problem mentally on the model. Once the model has been constructed one can read the results of what has been written. It is important to note that in order to read these results one needs the “mind’s eye”.

The mind’s eye has traditionally been a controversial issue in cognitive psychology. Another word for it is “homunculus” meaning “little man in the head”. Most cognitive psychologists disapprove of this concept of Mind’s eye on the premise that it reflects nonscientific theories of behaviour that were largely based on soul.

Self Assessment Questions

- 1) What types of thinking are involved in problem solving?

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2) What are the kinds of thinking processes?

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3) Describe Newell's Mental Model.

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1.6 CONCEPT OF INSIGHT PROBLEMS

There are two types of solutions to problems and these are (i) Insightful solutions and (ii) solutions without involving insight.

The essential characteristics of an insight solution to a problem is that the solution appears suddenly, without warning.

By contrast, problems solved without insight are solved gradually rather than suddenly. The solution process here involves a stepwise progression towards the solution.

For example, arithmetic and algebraic problems fall into the category of problems solved without insight. In this, the subjects themselves must be able to distinguish between these two types of solutions.

As the subjects solve a non insight problem, they should be able to tell that they are getting closer to the solution. For non-insight problems subjects generally have a greater feeling of warmth as they get closer and closer to the solution. This is because non-insightful problems are solved step by step and with each step the subject gets closer to the solution and thus warmer in each step.

As for insight problems there is no gradual approach to the solution and so subjects do not feel warmer until the solution actually appears.

Feeling of knowing and feeling of warmth reflect judgments that subjects make about their own knowledge. Such judgments are examples of metacognition. Metacognition refers to what one knows about the technique of how accurately one can assess one's own cognitive processes.

It has been shown that people's metacognitive assessments of their performance on noninsight problems are quite accurate. However, their metacognitive assessments of their performance on insight problems are not accurate, because an insight is not something that can be planned.

An insight is something that happens to the person, not something that a person decides to have. In insight solution, the problem is solved by the sudden illumination characteristic of insight.

Insight is preceded by a gradual process whereby relevant parts of the problem are identified. However, solvers may not be aware that this process is leading toward an insight.

Another aspect of insight problems is that the source of difficulty in some insight problems is the inability to see that something you already know is needed for the solution. Hints given within the context of the problem are fairly effective in facilitating subsequent insight. As the Gestalt psychologists often observe, people are generally not efficient at realising that a new problem can be solved with information already at their disposal.

People differ in their ability to select information that is relevant to the problem at hand. This ability to discover what is essential about situation is important as well as the ability to remember information that is relevant to the problem. This ability is called sagacity. Sagacity differs from learning in that it involves a sensitivity to detail, a discernment of what is important in a situation. Sagacity is the ability to see into the situation and to discriminate the important aspects of it.

The format in which the information is presented makes a difference in insightful problem solving. That is, one can give the information in a puzzle format or in a declarative format. The information given in the puzzle format leads the subject to discriminate the relevant information better than when the information is in declarative format. This is so because, the puzzle format leads the subject to process the relevant information in a way that makes it accessible for later use. On the other hand the declarative format leads to the acquisition of the relevant information, but in a way that makes it possible for the person to see its relevance for subsequent problem solving.

Select a word that can be interpreted in different ways. For example, the word *lake* can refer to a frozen or unfrozen body of water. Most people interpret the word to refer to an unfrozen body of water. A riddle can be constructed by requiring the problem solver to come up with the less accessible meaning in order to make sense of what is being described. If the subject is presented with a clue that the stone rested on the surface of the lake for 3 months, after which it sank to the bottom some 10 meters below., this would provide the solution that lake here refers to frozen one for 3 months and then running water lake afterwards.

1.7 LET US SUM UP

Problem solving is an important part of thinking processes. In general a problem is any kind of conflict or difference between one situation and another that one wishes to produce, that which is the goal.

Problem solving typically involves three major stages: preparation, production of solutions and evaluation of solutions that have been generated.

Problem solving can be done either with or without insight and utilises analytical, synthetic thinking along with metacognition.

This it can be said that, like many other cognitive processes, problem solving is a dynamic and complex process and involves many different types of thinking processes depending on the nature of the problem.

1.8 UNIT END QUESTIONS

- 1) What are the various categorisations of problems? Can you categorise your day to day problems into these categories?
- 2) What is the role of various types of thinking involved in solving different kinds of problems ?
- 3) Describe the four molar stages of problem solving.
- 4) Compare and contrast the role of productive thinking and structurally blind thinking in problem solving.
- 5) Emotional states can affect many cognitive processes. What can be the affect of these various emotional states on problem solving ?
- 6) Critically discuss the concept of insight problems and insightful solutions.
- 7) Solutions involving insight and solutions without involving insight – Differentiate.

1.9 SUGGESTED READINGS

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UNIT 2 STAGES OF PROBLEM SOLVING

Structure

- 2.0 Introduction
- 2.1 Objectives
- 2.2 Nature of the Problem
- 2.3 Generating Solutions
 - 2.3.1 Judging the Best Among the Likely Solutions
 - 2.3.2 Strategies for Problem Solving
 - 2.3.3 Some Specific Techniques of Problem Solving
 - 2.3.3.1 Generate and Test Techniques
 - 2.3.3.2 Means Ends Analysis
 - 2.3.3.3 Backward Search
 - 2.3.3.4 Planning Strategy
 - 2.3.3.5 Thinking Aloud
 - 2.3.3.6 Other Strategies
- 2.4 Creativity and Problem Solving
 - 2.4.1 Stages Involved in Creative Discoveries
- 2.5 Artificial Intelligence in Problem Solving
 - 2.5.1 Criticisms of the Computer Simulation Approach
- 2.6 Let Us Sum Up
- 2.7 Unit End Questions
- 2.8 Suggested Readings

2.0 INTRODUCTION

In this unit, we will examine the basic steps and strategies involved in problem solving – the ways to reach to solutions of the problems, and the various methods to solve different kinds of problems. For this, in particular, the following topics are discussed in detail. We will deal with Stages of Problem Solving, Techniques of problem solving, Creativity and Problem solving and the role of Artificial Intelligence in Problem Solving

2.1 OBJECTIVES

After completing this unit, you will be able to:

- Define problem solving and problems;
- Describe the various stages in problem solving;
- Analyse the various solutions; and
- Explain the steps to reach the best solution.

2.2 NATURE OF THE PROBLEM

The first step to solve the problem is to understand its different aspects and nature i.e. to figure out just what issues, obstacles and goals are involved. According to Greeno (1977), Understanding involves constructing an internal representation. For e.g. If you understand a sentence, you create an internal

representation or pattern in your head so that concepts are related to each other in the same way that they are related to each other in the original sentence.

In order to create this pattern in your head you must use background knowledge, such as the meaning of the various words in the sentence. In order to understand a problem you must pay attention to the important information in a problem. Furthermore, you must ignore the information that is irrelevant. As soon as the problem solver has decided which information is essential and which can be disregarded the next step is to find a good way to represent the problem. The representation can be done by using symbols, lists, matrices, graphs and visual images.

2.3 GENERATING SOLUTIONS

The next stage is finding variety of potential solutions for the problem. For this one can use one's past experiences and/or present resources and thinking critically about the problem. Several strategies can be used to solve the problems. Some methods are very time consuming but they will yield an answer. Other methods are less wasteful of time, but they may not produce a solution. These strategies are discussed in another section of the unit.

2.3.1 Judging the Best Among the Likely Solutions

At this stage we must evaluate each alternatives and outcomes of the problem. The objective of this step is to move closer to goal and learn about major obstacles and hidden costs of the particular solution and choose the best solution.

Carrying out the best solution

This stage involves actually working out the best solution. Various strategies can be adopted in reaching the solution. Algorithms and heuristics are the strategies which can be used depending upon the requirements of the problem. These are being dealt in the next section.

Evaluation of solution

In this the problem solver compares the solution with the representation of the problem. The path taken from the initial state to the goal state is checked as to whether it is specified as legal or not. Sometimes the evaluation stage leads to the conclusion that the problem has not been solved adequately, and thus one starts from an earlier stage, depending upon the source of the inadequacy.

2.3.2 Strategies for Problem Solving

An individual uses various kinds of methods or strategies to solve problems. Some strategies when used take a long time but definitely give an answer. On the other hand, there are some other strategies which take lesser time but do not always guarantee success. These strategies can be mainly classified under two categories, viz., (i) algorithm and (ii) heuristics. These two are discussed in the following section.

Algorithm

An algorithm is a specific procedure for solving a type of problem. An algorithm invariably leads to the solution if it is used properly, that is. It is a procedure of

steps that does guarantee a solution if one follows the steps correctly. The rules of multiplication constitute an algorithm because a correct answer is guaranteed if one follows the rules.

Consider anagram problems in which we try to reorganise groups of letters into words. Examples of algorithms are systematic and unsystematic random search techniques. Unsystematic random search means that we try out all kinds of possible answers but make no attempt to be orderly in our search and keep no record of our previous attempts. As a consequence we may repeat a response that has already proved to be wrong. In systematic random search we try out all possible answers using a specified system. This method is somewhat more efficient than unsystematic random search, but it is highly time consuming when there are many alternative answers. If you are given a 3 letter anagram, YBO, with instructions to unscramble it, proceed with a systematic random search: YOB, BYO, BOY, ! However, notice how time consuming it would be to use a systematic random search to solve a longer anagram, such as LSSTNEUIAMYLOU.

Heuristics

In this strategy an individual does not go for all the alternatives to solve problems but choose some most relevant alternatives. This is kind of short cut rule which takes lesser time but does not guarantee success. Heuristics are rules of thumb that help us simplify and solve problems.

Heuristics do not guarantee a correct solution to a problem but when they work, they permit more rapid solutions. A heuristic device for solving the anagram problem would be to look for familiar letter combinations. For e.g. how many words can you make from the pool of letters DWARG? In this anagram we can find the familiar combinations *dr* and *gr*. We may then quickly find draw, drag, and grad. The drawback to this method, however, is that we might miss some words.

Psychologists have paid more attention to how humans use heuristics than how they use algorithms. Let us look at some of the heuristics as strategies in solving problems. Problem solvers can use one or more of these heuristics as they attack a problem.

Self Assessment Questions

- 1) Define problem and problem solving.

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- 2) Discuss the nature of the problem.

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3) How do we generate solutions to the problem?

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4) Discuss strategies for problem solving.

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5) What is algorithm?

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6) What is heuristics?

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2.3.3 Some Specific Techniques of Problem Solving

The way to solve a problem depends to a great extent on the nature of the problem itself. For example, if you want to go from New Delhi to Chennai you will call various travel agents for information regarding the various available options for traveling and staying. However, if you want to know your bank balance you will not call a travel agent for assistance but go to your bank or nearest ATM or use net-banking. This is called domain specific problem solving approaches, that is the solution that work only for a limited class of problems. In the following section, a certain class of general, domain independent techniques of problem solving is discussed.

2.3.3.1 Generate and Test Techniques

To understand this let us begin with a simple problem:

“Think of ten words beginning with letter c that you eat or drink.”

The process that most of us use to arrive at the solution to such a problem generally involves what is called generate and test technique. It consists of generating possible solutions and then testing them. For example, for the above problem of generating a list of things to eat or drink beginning with letter c, some of the names that often come to our mind that sound as if beginning with c but which actually do not (like ketchup) and some that start with c but are not names of eatables/drinks (like cable, can) might have come to your mind as a solution but on thinking you would have discarded these words. This explains the process of thinking of possible solutions (generating) and then seeing if those possibilities met all the criteria (testing).

Generate and test is a technique that loses its effectiveness very rapidly when there are many possibilities and when there is no particular guidance over the generation process. For example, if you forget your ATM pin, the technique might eventually work but your frustration level by that time might exceed beyond your willingness to work on the task. Moreover, if we do not have a way to keep track of the possibilities that we have already tried, along with the ones that we still have to try, we might be further frustrated.

Generate and test can be useful when there aren't a lot of possibilities to keep track of. If you have lost your keys somewhere between your classroom and college cafeteria the technique can be easily used to help search the keys.

2.3.3.2 Means-ends Analysis

It is a strategy in which the problem solver divides the problem into a number of sub problems, or smaller problems. Each of these sub problems is solved by detecting the difference between the original state and the goal state and then reducing the difference between these two states. The name means ends analysis fits the process, because it involves figuring out the “ends” you want and then figuring out what “means” you will use to reach those ends. Every day we all solve problems by using means ends analysis. Means ends analysis involves subgoals to eliminate the difference between the current state and the condition for applying desired operator.

Our original state at one point is an equation

$$2s - 10 + 5 = s + 5 + 8$$

and our goal state is an equation with a single s alone one side. We reduced the difference between the two states by adding +5 to each side of the equation and subtracting s from each side of the equation.

This strategy repeatedly compares states and seeks operators, establishing subgoals and finding ways to reach the sub goals, all on the way to finding a path to the final goal.

2.3.3.3 Backward Search

With the backward search heuristic, the problem solver starts at the goal state. Sometimes it is useful to start at the goal state of a problem and attempt to work backward to the initial state. In solving a paper-pencil maze, it may be easier to see the correct path by starting at the end. Working backwards can be a very useful heuristic, particularly for problems that contain a uniquely specified goal state. For example, a backward search would be ideal for a maze with many paths out of the beginning point yet only one path leading from the goal.

The reason working backward helps lies in the subgoals that one begins to see by starting with the final goal. Once the problem solver can envision a string of subgoals projecting backward from the goal state, then going about solving the subgoals in a forward direction can be readily accomplished. Working backward is only viable when the goal state is uniquely well defined (Wickelgren, 1974).

2.3.3.4 Planning Strategy

In this heuristic, the problem is divided into two simple aspects and complex aspect. First, the simple aspect of the problem is solved leaving behind the complex one, and thereafter the complex aspect is taken and is solved. It is particularly useful if the aspects that are ignored can easily be worked into the solutions to the complicated problems.

One common kind of planning strategy is analogy. In analogy, a solution to an earlier problem is used in order to help with an original problem. The current problem is solved on the basis of past experience of solving similar problems. This heuristic looks for similarities between a current problem and one solved in the past. Try to solve the anagram BODUT. By thinking of words D, O, U will simplify the problem information. The usefulness of the planning strategy depends on the extent to which the solution to the simple problem will be helpful when the complex problem is considered.

2.3.3.5 Thinking Aloud

Ericsson and Simon referred to the method of thinking aloud as a Method for Studying Human Problem Solving is referred too as concurrent verbalisation, that is verbalisation of information at the time the subject is attending to it. This is to be distinguished from *retrospective verbalisation*, in which the subject is asked about cognitive processes that occurred at an earlier point in time.

Concurrent verbalisation relies on short-term memory whereas retrospective verbalisation relies on long-term memory.

When subjects think aloud, they put into words a process that normally takes place nonverbally. This provides a description of the subject's solution process. A verbal description so obtained is *called a protocol*. Although there may be omissions in these protocols, they still contain a great deal of useful information.

Newell (1977) recommended a series of steps in order to clarify the protocol.

1st Step: First, the protocol needs to be divided into phrases, which are descriptions of single acts.

2nd Step: Second, the experimenter constructs a *problem behaviour graph*, a concrete description of the way in which the subject moves around in the problem space. This description can be used as the basis for a production system designed to model the subject's behaviour.

Although concurrent verbalisation is widely used, there is evidence suggesting that it may interfere with some aspects of the problem-solving process. For example, Schooler, Ohlsson, and Brooks (1993) did a study in which subjects were interrupted while trying to solve an insight problem.

One group was then asked to describe their problem-solving strategies, while another group engaged in an activity irrelevant to the problem. Subjects then resumed attempting to solve the problem.

The group that had verbalised their strategies were less likely to solve the problem than the group engaged in an irrelevant activity. Schooler, Ohlsson, and Brooks concluded that there are “non reportable or unconscious processes” that lead to insightful solutions, and these are interfered with by verbalisation.

These non reportable processes may be memory searches that lead to the recovery of the items needed for the solution. These processes may be disrupted by the attempt to verbalise the solution process. Therefore, researches using think-aloud techniques should also consider including silent control groups to determine whether verbalisation influencing performance.

2.3.3.6 Other Strategies

Some other strategies that people often employ in problem solving include:

Abstraction: This technique involves solving the problem in a model of the system before applying it to the real system.

Divide and conquer: While using this approach to problem solving, people break down a large, complex problem into smaller, solvable problems.

Hypothesis testing: This involves assuming a possible explanation to the problem and trying to prove (or, in some contexts, disprove) the assumption.

Lateral thinking: Many problems involve approaching solutions indirectly and creatively and this involves the use of lateral thinking.

Method of focal objects: This approach involves synthesizing seemingly non-matching characteristics of different objects into something new and reaching to a solution.

Reduction: Problem solving may also be done by transforming the problem into another problem for which solutions exist and this is called reduction.

Research: This involves employing existing ideas or adapting existing solutions to similar problems.

Root cause analysis: involves eliminating the cause of the problem.

Trial-and-error: This is one of the most widely studied methods in psychology and involves testing possible solutions until the right one is found.

Brainstorming: This approach is especially used among groups of people wherein a large number of solutions or ideas are suggested by various members of the groups and later these ideas are combined and developed until an optimum solution is found.

Self Assessment Questions

1) What are some of the specific techniques of problem solving?

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2) What is involved in “generate and test” technique?

3) What do you understand by the term “Means Ends “ analysis?

4) What is backward search in problem solving?

5) Discuss “thinking aloud” as a method for studying human problem solving.

2.4 CREATIVITY AND PROBLEM SOLVING

As discussed in Unit1, many of the problems are called insight problems, and are believed to have a solution that comes from insight. The process by which insight comes is not well understood. However it is strongly believed that creativity plays a vital role in insight and vice versa.

Although the term is difficult to define precisely, many psychologists believe that creativity has to do with appropriate novelty, that is, originality that suits some purpose (Hennessey & Amabile, 1988).

Appropriate ideas that lack novelty are mundane; conversely original ideas that do not address some problem in a useful way are bizarre. Cognitive scientists refer to creativity as a combination, or recombination, of knowledge, information or mental representations. In other words the person who has created it knows about it, and also has depicted it. (Dartnall, 2002). Creative problem solving forms the essence of insight problem solutions. Insight seems to involve at least three separate problem-solving skills (Davidson, 1986; Davidson & Sternberg, 1984) and these are (i) selective encoding (ii) selective combination (iii) selective comparison. These are discussed below.

- 1) *Selective Encoding.* When we try to solve a new problem, we are often overwhelmed by large amounts of useless information. An insight arises when we determine which information is relevant for further consideration. Sir Alexander Fleming discovered penicillin through selective encoding. Fleming's attempts to grow bacteria had been disrupted by the appearance of a mold in his culture. Rather than dismissing this mold as irrelevant to his original experiments, he realised that the mold's bacteria has a killing ability that was relevant to a greater medical concern, that is the need for antibiotics to kill disease-causing organisms.
- 2) *Selective Combination:* When we have a problem to solve, we often have all the pieces of the solution, but we do not know how to put them together. An insight arises when we discover a novel way of combining the elements of the solution.

For example, Darwin's construction of the theory of evolution involved selective combination. The various facts about natural history had been available to him for a long time. What Darwin did was to combine this information into an innovative and coherent theory.
- 3) *Selective Comparison.* When we solve a problem, we often use a model solution that we encountered in the past. Insight occurs when we discover that a more novel comparison leads to unforeseen consequences.

To give an example, Kekule's discovery of the structure of the benzene ring involved selective comparison.

In a dream Kekule saw a snake curl back on itself and catch its own tail. Upon waking, he realised that this was the structure he had been seeking. His insight was to discern the underlying similarity between his dream image and the benzene ring.

As the above examples suggest, insight is an important aspect of the creative process. Even though the laboratory puzzles and problems that we have been discussing in this Unit as examples bear little resemblance to the kinds of problems that Fleming, Darwin, and Kekule worked on, they all involve insight in that a solution suddenly comes to mind. They also share another property, that is, the person begins in the dark, not knowing what to do. What factors promote creative solutions to important problems?

2.4.1 Stages Involved in Creative Discoveries

Many creative discoveries seem to occur in these four stages:

- 1) Preparation
- 2) Incubation

- 3) Insight
- 4) Verification.

As discussed, Creativity is the ability to see something new in something quite ordinary.

Preparation: First a goal is set. Then potentially relevant information is gathered, sometimes deliberately, sometimes by accident.

Incubation: This preparation done, a period of apparent inactivity, that is incubation can set in. Incubation may involve unconscious mental activity, or it may simply be a period of waiting for some important missing link to fall into place.

Insight: The moment of insight (also called illumination) often involves familiar elements coming together in new ways. The mathematician Henri Poincare wrote, “To create consists of making new combinations of associative elements that are useful” (1929).

Verification: The final step, verification, tells whether a new combination is, in fact, useful. Two characteristics stand out in the creative person:

The first is a clear sense of purpose: An invention, a painting, a musical composition, or any other creative product is a solution to a problem. Without a clear goal, a clear problem to solve, nothing would be created. The second outstanding characteristic of creative people is their store of knowledge and techniques. Inventors have to know both the content and the techniques of their field, composers have to know music and the craft of composition, and scientists must know the facts and theories of their field and master the mathematical and technical tools of the trade. Because “creativity” has an almost mystical connotation, it is easy to forget how basic and indispensable purpose and knowledge are.

Self Assessment Questions

- 1) How are creativity and problem solving related?

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- 2) What are the 3 problem solving skills that insight involves? Give examples

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3) What are the various stages in creative discoveries?

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2.5 ARTIFICIAL INTELLIGENCE IN PROBLEM SOLVING

Researchers studying problem solving propose problem space hypothesis which states that “every possible state of affairs within a problem corresponds to a particular mental node and the entire set of nodes occupy some mental area and this area together with the mental graph is a problem space”.

This problem space hypothesis has been used to create expert systems called computer programmes designed to model the judgments of one or more human experts in a particular field.

Expert systems contain a knowledge base that store facts relevant within that field. They typically also contain a set of inference rules, a search engine that the programme uses to search knowledge base using inference base and some interface or means of interacting with a human user who has a question or problem for which he/ she is consulting the expert system.

These are computer programmes that solve problems in ways that are similar to the intelligent way in which humans solve problems are called artificial intelligence approaches and have been found to be extremely influential.

2.5.1 Criticisms of the Computer Simulation Approach

Not all researchers agree that computer simulation can capture the way that people think when they solve problems. Some people argue that thinking is just too complex to be mimicked by a machine. However, as we know, computer programs can produce some solutions to very complicated problems. Current experience and researches suggest that there appear to be no reason, in principle, why computer program should not approach (or surpass) the complexity of human thought.

Other criticisms derive from the belief that whatever it is that computer programs do it does not really count as thinking and problem solving. People who express this belief often ally themselves with the German philosopher Heidegger (1968).

The properties of computer programs that they can represent the chain of inferences leading from one state to another are not the essence of thinking for Heidegger who strongly propound that ‘Computer programmes are good stimulators of such processes as reasoning and calculating. However, the essence of thinking lies behind such processes as reasoning and calculating and computer programmes are not reducible to them. It is the subjective origin of thinking-the

concern with the fundamental problem of being alive in the world which the computer programmes do not capture. Despite these arguments, in the current times artificial intelligence is widely used for problem solving and appears to have promising future.

Self Assessment Questions

- 1) How does artificial intelligence function in problem solving?

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- 2) What is meant by computer simulation approach in problem solving?

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- 3) What are the criticisms against computer simulation? Discuss

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2.6 LET US SUM UP

Problem solving involves both domain specific and general strategies that people may use. General strategies (like generate and test, means-ends analysis, reasoning by analogy) are believed to be general strategies of problem solving that people use in wide variety of situations. In contrast there are domain specific strategies that are suitable in one particular situation and problem but not for others.

Many expert systems that represent artificial intelligence are specially designed computer programmes that mimic a human expert in a specific field. However, there are many unanswered questions pertaining to the utility of artificial intelligence in problem solving. Insight problem solving has been found to be related to creativity. In summary, problem solving is a multi step process and may be facilitated by individual characteristics such as creativity.

2.7 UNIT END QUESTIONS

- 1) What are the stages in problem solving? Highlight the stages with a problem from your day to day life.
- 2) Compare and contrast the generate- test, the means ends and the backward search method of problem solving.
- 3) Discuss “thinking aloud as a method of studying human problem solving
- 4) Discuss “other strategies” in problem solving. For example, abstraction, divide and conquer etc.
- 5) Critically evaluate the utility of artificial intelligence in problem solving?
- 6) Compare and contrast the general stages of problem solving with the stages of creative problem solving.
- 7) Discuss the concept of thinking aloud approach of problem solving.

2.8 SUGGESTED READINGS

Hunt, R. R., & Ellis, H.C. (2006). *Fundamentals of Cognitive Psychology*. New Delhi: Tata McGraw Hill.

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UNIT 3 THEORETICAL APPROACHES TO PROBLEM SOLVING

Structure

- 3.0 Introduction
- 3.1 Objectives
- 3.2 Approaches to Problem Solving
 - 3.2.1 Traditional Approaches
 - 3.2.2 Gestalt Approaches
 - 3.2.3 Information Processing and Computer Simulation Approach
 - 3.2.3.1 The General Problem Solver
 - 3.2.3.2 Mean end Analysis
 - 3.2.3.3 Wickegren's General Problem Solving Strategies
- 3.3 Newell's Approach
 - 3.3.1 Summary of the Problem Space Hypothesis
- 3.4 Problem Solving as Modelling
- 3.5 Let Us Sum Up
- 3.6 Unit End Questions
- 3.7 Suggested Readings

3.0 INTRODUCTION

The different forms of thinking behaviour including problem solving vary along a number of dimensions. The degree to which we are conscious of our thought processes can vary considerably. We tend to be conscious of the products of problem solving rather than the processes themselves. Furthermore, even these conscious products may not be recalled accurately in retrospect by people. Problem solving tasks can also be more or less directed. Some problem solving tasks are directed towards specific, well-defined goals, whereas other forms are rambling and goal-less. Thinking episodes directed at problem solving also differ in terms of the amount of knowledge that comes into play to achieve a goal and these may be knowledge-lean or knowledge-rich. Most of the early research on problem solving has examined directed thinking in knowledge-lean situations that have specific goals (i.e. puzzles). Later research considers more knowledge-rich situations (e.g. expert problem solving). In the present unit we focus on the various theoretical approaches to understanding the process and nature of problem solving.

3.1 OBJECTIVES

On completing this unit, you will be able to:

- Explain the theoretical aspects of problem solving;
- Give a historical account of problem solving; and
- Describe the various theories related to problem solving.

3.2 APPROACHES TO PROBLEM SOLVING

In this unit, we will examine the theoretical understandings of nature and process of problem solving from the traditional to the most recent viewpoints. The theoretical models that are discussed in detail include the traditional models of problem solving, Gestaltists Theories, Information processing and computer simulation, The General Problem Solver (GPS), Wickelgren's general problem solving strategies and Newell's approach to understanding Problem Solving.

3.2.1 Traditional Approaches

Traditional approaches explain problem solving in terms of principles of associative learning derived from the studies of classical and instrumental conditioning. According to some theorists an individual enters a problem situation with an existing complex of stimulus response associations as a result of prior experience. The problem is more likely to elicit some of these associations than others, with a clear implication that problem difficulty will depend on the strength of the correct association relative to the strength of other incorrect associations. In the course of problem solving, the associative complex gets rearranged as some tendencies are weakened through extinction (failure) and other strengthened through reinforcement (success). This viewpoint stresses the transfer of prior learning to the problem situation and to the learning which takes place during problem solving.

3.2.2 Gestalt Approaches

A different view of problem solving was proposed by the gestalt psychologists. These theorists emphasised the importance of the structure of the problem situations and the formation of new combinations of old ideas. They were particularly interested in how people solve problems by rearrangement of objects. A well known example is the problem described by Kohler (1925) in his book, *The Mentality of Apes*. Kohler hung some fruits from the top of a cage to reach it. The cage contained several sticks and crates. The solution depended on finding a correct way to rearrange the objects. According to the Gestalt analysis, solving the problem required the reorganisation of the objects into a new structure. Gestaltists argued that discovering the correct organisation usually occurred as a flash of insight. Insight is the sudden discovery of the correct solution following a period of incorrect attempts based primarily on trial and error. Insightful solutions seem to occur in a flash.

Gestalt psychologists distinguished between reproductive and productive thinking (Wertheimer, 1959). Reproductive thinking entails the application of tried and true paths to solution. The thinker reproduces a series of steps that are known to yield a workable answer by using rote memory. Productive thinking on the other hand, requires insight and creativity. According to gestalts view the thinker must see a new way of organising the problem, a new way of structuring the elements of thought and perception. A classic problem calling for productive insightful thinking is the nine dot problem shown below:

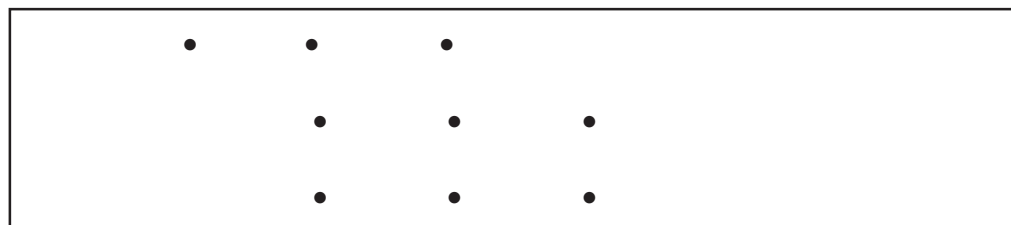


Fig. 1: The Nine dot problem

The task (problem) is to connect the nine dots with just four straight lines, without lifting your pencil from the paper in drawing the lines. To think productively in this problem situation one must restructure the problem, to throw off the unnecessary assumption that the lines must lie within the visual boundaries.

Self Assessment Questions

- 1) Describe traditional approaches to problem solving.

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- 2) Describe Gestalt approaches to problem solving.

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- 3) Compare and contrast the traditional and Gestalt approaches.

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3.2.3 Information Processing and Computer Simulation

A number of researchers have tried to program computer to perform tasks that human beings do. Such computer simulation research has had a profound influence on psychology of human cognitive processes. The method consists of programming a computer to work in a specified manner and comparing its performance to that of human subjects given the same tasks. Researchers employing computer simulation have made major contributions to the development of information processing view of problem solving.

A problem requires a person not only to register information from the environment but also to operate on, modify, or transform that information in some way in order to reach a solution.

Solving problem also requires the retrieval of both factual and procedural knowledge from long term memory. Especially for longer problems, reaching a solution might involve repeated storage and retrieval of information generated early in the problem for use in later stages. Even this brief listing clearly indicates

that problem solving is not a single cognitive process but rather involves a number of activities which need to be properly executed and organised to be successful.

The most promising kind of theory in the early 1980s involves computer simulation. In the last couple of decades a number of computer simulation theories of problem solving have emerged. The general problem solver (GPS) developed by Newell, Shaw and Simon (1958). It introduced a way of looking at problem solving which has influenced virtually all problem solving theories.

3.2.3.1 The General Problem Solver (GPS)

The program was equipped with the equivalent of:

A limited capacity working memory characterised by rapid storage and retrieval

A large capacity long term memory characterised by relatively low storage and retrieval

A serial processor that performs one operation at a time

A reliance upon heuristics, rather than algorithms that would require a large number of high speed calculations.

Newell and his colleagues collected verbal protocols that were used and kept as a record of people talking aloud as they solved problems. Then they transcribed these lengthy records carefully to see if they could find general heuristics that emerged. It introduced a way of conceptualising problem that is adopted in most contemporary theories of problem solving.

The General Problem Solver (GPS) assumes that the problem solver represents a problem as a problem space which consists of a set of nodes, each node corresponding to a state of knowledge about the problem. The problem solver begins at the initial state of knowledge and seeks to convert it into the goal state by applying operators, which are actions that are permitted in order to move from one state of another. Problem solving, then, requires a constructive search during which the solver builds up a problem space, which leads from the initial to goal state using a set of allowed operators.

3.2.3.2 Means End Analysis

This was recognised as a general problem solving heuristic which involves a search for operations that will reduce the difference between present state of knowledge and the goal state. In particular, means-end analysis involves the following steps:

Set up a goal

Look for a difference between the current problem state and the goal state.

Look for a method to decrease or eliminate the difference between the two stages.

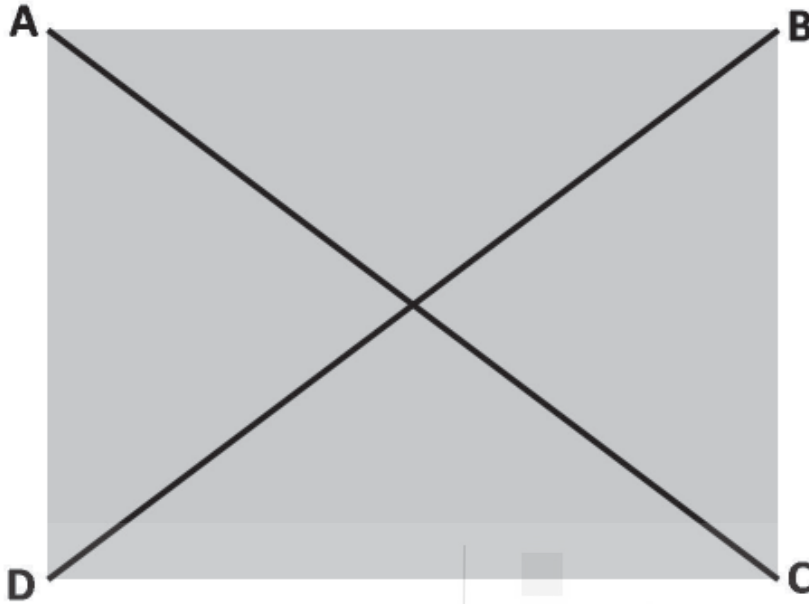
Set as a sub goal which is the application of that method.

If necessary apply means- ends analysis to apply to the sub goal.

Thus, the main heuristic used in GPS involves setting up goals and sub goals. In fact, this strategy can be expressed very precisely as a production system, that is, as a set of if – then pairs stored in the computers memory as production.

An illustrative geometric problem:

The problem is that ABCD is a rectangle; prove that AD and BC are same length.



Steps in problem solving:

Represent the problem as a proposition or in visual form

Determine the goal.

Break down the goal into sub goals.

Select a problem solving technique

Solution is:

It can thus be proven that triangles ACD and BDC are congruent if one could prove that two sides included angles are equal. (We reason from goal to sub goal, proving the triangles congruent, from the sub goal to another sub goal improving the sides and angle equal), and so on, until we reach a sub goal that we have a ready means of obtaining).

The 3 strategies that we can use to solve this problem are difference reduction, means-end-analysis, and working backwards and these three strategies are extremely general and can be applied to virtually any problem.

3.2.3.3 Wickelgren's General Problem Solving Strategies

Wickelgren's view of problem solving is based on information processing theories such as GPS. According to this view, a formal problem contains three types of information:

A statement of the initial state.

Description of the goal state.

Description of set of operation or transformations.

A solution can be defined as a sequence of state or actions which helps to represent in a diagram called the State Action Tree. The nodes or branch points on the tree represent all the possibly different problem states that could result from all the different action sequences.

The branches on the tree represent the possible actions that could be made at the particular state of knowledge. The given state is represented by the single node at the top level of the state action tree, and the goal state is represented by the indicated node in the lowest level of the tree.

For this schematic tree, we assume that from the goal state there are only two possible actions that the person can take. One of which starts the person on the path toward the goal, the other of which does not.

Having chosen one of these (thereby leading the person to state level 1), the person is then faced with a new set of possible actions. Here, we arbitrarily assume that there are three possible actions that could be taken at either of the state level 1 nodes.

This successive making of choices goes on and on until the person either reaches the goal state or finds himself at a dead end. Thinking about state action trees is the fact that as you get further into a problem (i.e. lower and lower levels in the tree) the number of possible action sequences increases rapidly. Wickelgren argues that there are seven general problem solving techniques for searching the state action tree.

- i) *Inference*: Deducing from the explicitly stated goals givens, and operations stated in the problem
- ii) *Classification of action sequences*: organising possible sequences of actions (or operations) that are equivalent as far as the problem is concerned. These are called equivalence classes.
- iii) *State evaluation and hill climbing*: state evaluation involves defining a quantitative evaluation function that can be calculated for all possible problem states and hill climbing involves choosing the action to be taken next that will have an evaluation that is closest to the goal.
- iv) *Subgoals*: This stage involves searching for sub goals involve breaking down the problem into sub goals to make it simpler.
- v) *Contradiction*: deriving some inference from the givens that is inconsistent with the goal state to narrow down the state action tree in a systematic fashion by eliminating possibilities that could possibly not work.
- vi) *Working backward*: It involves beginning with the goal state and working backward from it.
- vii) *Finding relations between problems*: finding relations between the new problems and problems solved previously.

Self Assessment Questions

- 1) Describe and delineate the characteristic features of information and computer simulation approach to problem solving.

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2) What do you understand by the term General Problem Solver.?

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3) Describe the Menan end analysis with examples

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4) Put forward in detail the general problem solving strategies of Wickelgren.

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3.3 NEWELL'S APPROACH

It is very natural to think of problems as being solved through the exploration of different paths to a solution. Taker maze for example. In this, you start from a point outside the maze and then progress through it to the centre. On your way, you reach junctions where you have to choose between going straight on, turning to the left or right, or turning back. Each of these alternative paths may branch again and again so that, in the maze as a whole, there are hundreds of alternative paths (only some of which will lead to the centre). Different strategies can be used to find one's way through a labyrinth.

The strategies provide you with a systematic method for searching the maze and help you to select one from among the many alternative paths.

Newell and Simon used parallels to these basic ideas to characterise human problem solving behaviour.

They suggested that the objective structure of a problem can be characterised as:

- i) a set of states, beginning from an initial state (e.g. standing outside the maze),
- ii) involving many intermediate states (e.g. moving through the maze), and
- iii) ending with a goal state (e.g. being at the centre of the maze).

The application of these operators (turn left, go straight etc.) results in a move from one state to another. In any given state there may be several different operators that apply (e.g. turn left, turn right, go back) and each of these will generate numerous alternative states. Thus, there is a whole space of possible states and paths through this space, and only some of these will lead to the goal state. *This problem space describes the abstract structure of a problem.*

3.3.1 Summary of The Problem Space Hypothesis

For any given problem there are a large number of alternative paths from an initial state to a goal state; the total set of such states, as generated by the legal operators, is called the basic problem space.

People's problem solving behaviour can be viewed as the production of knowledge states by the application of mental operators, moving from an initial knowledge state to a goal, knowledge state.

Mental operators encode legal moves that can be made. There are also restrictions which disallow a move if certain conditions hold.

People use their knowledge and various heuristic methods (like means-end analysis) to search through the problem space and to find a path from the initial state to the goal state.

All of these processes occur within the limits of a particular cognitive system. That is, there may be working memory limitations and limitations on the speed with which information can be stored and retrieved from long-term memory.

Newell's approach, which is based on this problem space hypothesis, propounds that the knowledge level rationalises behaviour in terms of the reasons that an agent has to believe that certain actions will lead to achieving certain goals. In this sense knowledge is a means to an end, a resource for behaviour.

The goal of problem solving is to select one of the possible actions.

3.4 PROBLEM SOLVING AS MODELLING

More recently, a different view is being explored, namely the view of problem solving as modeling.

The idea is that problem solving is the construction of situation specific model or case model.

From a knowledge level perspective the person's perception of the world is through knowledge alone. A goal therefore must correspond to the desired state of one's knowledge about the world.

Consequently this knowledge must refer to the specific systems that the goal is about. The case model thus summarises the person's understanding of the problem, and allows it to eventually conclude that the goal has been reached.

The actions are the means by which the person interacts with the world. Since at the knowledge level the person's perception is through knowledge, the interaction must be viewed as a way of obtaining knowledge about the reality. Thus one may say that actions of perception and interactions fit in this scheme.

In the problem solving as modeling, the actions are not the goal of problem solving but are themselves a means to an end. That end is the construction of a model which will help in eventually achieving the goals. Whether it is the domain model or task model the construction of the model should be such that it should lead to the goal.

For instance, in making a domain model, it is not just packaging statements about the domain, but it should involve augmenting statements with a series of assumptions about how the information about the systems is connected.

In regard to task model, it embodies assumptions about the meaning of goals. For example, if a diagnostic task is modeled as a process to generate and test over components of a system, then one implicitly assumes that the fault one is looking for can be localised in a component.

Thus, modeling a task corresponding to a goal is to make more precise what one *assumes* that goal to mean.

The role of the problem solving method is to tie domain and task models together in an argument on what accomplishing the task means in terms of the available models. This is termed as competency theory.

To give an example, a heuristic classification problem solver assumes that the solution to its problem is within the differential and it is what the problem solver believes that it can say about the problem. This actually defines its competence.

In addition the competence theory also talks about what rationality means. A heuristic classification problem solver will use the knowledge and actions pertaining to rationality to reduce the size of the differential. This is called *specialised principle of rationality*. It contains the basis for all “why” questions about the system’s behaviour.

This model is the case model and it is obtained from the competence theory through actions. Specific control regimes (e.g., data-driven or hypothesis-driven heuristic classification) correspond to different ways of operationalising the specialised principle of rationality.

The configuration of models, tasks and methods entails a set of assumptions that together can be interpreted as a model of the problem. The goal of problem solving is to instantiate this model by making it realistic.

This can be done by making derivations from

- i) the case-specific knowledge obtained by the person’s actions and
- ii) the assumptions embodied in the domain and task models.

The form of the case model is determined by the selection of problem solving method.

In this view problem solving is no longer an input-output process (as in KADS-I). It is also not a means to select actions (as in Newell’s knowledge level theory). It is also not a model transformation process (as in Components of Expertise). It is in fact a process of organising knowledge by making assumptions (i.e., constructing a model) that allow one to conclude (in effect, only assume) that the task is accomplished.

Successful problem solving is a matter of making the right assumptions and exploring their consequences.

Problem solving is thus viewed as the ‘creation’ of a suitable case model and the interaction with the world is only a resource for this. It is almost a side-effect in the process of maintaining an internal organisation and identity.

Self Assessment Questions

- 1) Describe Newell’s approach to problem solving.

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- 2) What do you understand by the term problem space hypothesis?

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- 3) Summarise the Problem space hypothesis.

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- 4) What is problem solving as modeling?

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- 5) Discuss successful problem solving.

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3.5 LET US SUM UP

Like most of the psychological and cognitive constructs problem solving has also been construed in different light by different researchers following different schools of psychology. The more traditional approaches explained problem solving in terms of principles of associative learning derived from the studies of classical and instrumental conditioning.

Gestaltists viewed it differently and emphasised the importance of the structure of the problem situations and the formation of new combinations of old ideas. Since then we have observed many different approaches to understanding problem solving in terms of the Information Processing and Computer Simulation approach, the General Problem Solver (GPS) approach, Wickelgren's general problem solving strategies and Newell's approach which is based on problem space hypothesis.

As knowledge and research progresses it is likely that one may come up with more comprehensive theories of problem solving.

3.6 UNIT END QUESTIONS

- 1) What are the traditional approaches to understand problem solving? Think of some problems that you can explain based on these approaches.
- 2) Explain Wickelgren's approach of general problem solving strategies.
- 3) Compare the Gestalt approach of problem solving with information processing approach to problem solving.
- 4) Newell's problem solving approach rests on a famous hypothesis in the literature of problem solving. Name and explain this hypothesis.
- 5) Critically discuss Newell's approach to problem solving.
- 6) What do you understand by the term "General Problem Solver". Explain with examples.
- 7) Do you think that a single approach amongst the approaches discussed in this chapter is sufficient to explain all kinds of problems and problem solving that we face.

3.7 SUGGESTED READINGS

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UNIT 4 IMPEDIMENTS TO PROBLEM SOLVING

Structure

- 4.0 Introduction
- 4.1 Objectives
- 4.2 Effective Problem Solving
- 4.3 Other Methods for Problem Solving
 - 4.3.1 Einstellung
 - 4.3.2 Understanding the Problem
- 4.4 Overcoming the Constraints
 - 4.4.1 Typical Processes in Solving a Problem
- 4.5 Impediments to Problem Solving
- 4.6 Productive Problem Solving and Impediments Thereof
 - 4.6.1 Impediments of Productive Problem Solving
- 4.7 Problem Solving in Team and Small Groups
- 4.8 Critical Thinking in Problem Solving and Impediments
- 4.9 Other Barriers to Problem Solving
 - 4.9.1 Perceptual Blocks
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 - 4.9.4 Expressive Blocks
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- 4.10 Teaching and Learning Strategies that Enhance Problem Solving Skills
 - 4.10.1 Pedagogical Stuff
 - 4.10.2 Promoting Transfer
 - 4.10.3 Dialogue
- 4.11 Functional Fixedness
- 4.12 Using Complete or Incorrect Representations
- 4.13 Lack of Problem Specific Knowledge or Expertise
- 4.14 Let Us Sum Up
- 4.15 Unit End Questions
- 4.16 Suggested Readings

4.0 INTRODUCTION

You might have come across many situations when your attempts at problem solving may have failed. This is largely because the problem space is not adequately searched or because it is not represented well in the first place. There are numerous factors that are influential impediments to problem solving.

Einstellung (or set or mental set) and functional fixedness are classic obstacles to both proper representation and search identified by the Gestalt psychologists. However, there are other impediments to problem solving also. In this chapter we will study some of these impediments to problem solving.

4.1 OBJECTIVES

After completing this unit, you will be able to :

- Define problems;
- Differentiate between problems and dilemmas;
- Define and describe Mental Set;
- Describe Luchin's Water Jar Problem;
- Explain impediments to problem solving;
- Define Functional Fixedness;
- Explain Incomplete or Incorrect Representations; and
- Analyse Lack of Problem Specific Knowledge or Expertise.

4.2 EFFECTIVE PROBLEM SOLVING

Depending on the kind of dilemma or problem, there are a number of models that can help people to think through their approaches to decision-making.

Haynes' model

This suggests a 3-step approach in the form of reflective questions, for dealing with ethical decision-making dilemmas and problems

When working out a solution to the problem, there are a few questions one should pose to oneself and these are for instance, "If this particular solution is considered what will be the consequences and would there be more benefits vis a vis harmful effects?"

Hall's model (2001)

Alan Hall (University of Waikato) offers a set of questions that educators can use to help consider all things before deciding what they ought to do when confronted with an ethical problem, and how they will do it:

What is the basic issue concerned with the problem?

What principle is at risk?

Who will benefit?

Will benefits be more than harm?

4.3 OTHER METHODS FOR PROBLEM SOLVING

4.3.1 Einstellung

It is the term used by the Gestaltists to describe the tendency to set the mind into a routine approach to problem solving. When we considered Wertheimer's laboratory problems, we noted that sometimes previous experience can blind a person to simple solutions. The experiments of Luchins (1942; Luchins & Luchins, 1950, 1994a, 1994b) are among the most interesting demonstrations of the way in which repeating a particular problemsolving method can make a person blind to alternative ways of solving the problem.

Luchins (1942) discovered set or Einstellung effects with the water jar problems. In this problem it is required to measure out a desired quantity of water using three jars with different capacities. Jars used have no gradations on them so they have to be filled up to the top to measure amounts that result in the desired quantity.

Luchin's Water Jar Problems

	Jar Sizes			
	A	B	C	Goal
Problem 1	21	127	3	100
Problem 2	14	163	25	99
Problem 3	18	43	10	5
Problem 4	9	42	6	21
Problem 5	20	59	4	31
Problem 6	23	49	3	20

For instance, suppose the desired quantity was 5 cups and Jar A held 10 cups, Jar B held 4 cups, and Jar C held 1 cup, the solution would be to fill A first. Next from A pour into B once, and then pour from B into C once (A-B-C). Try all six problems in above Table before proceeding.

Luchins found that problem solvers adopt a set in solving these problems. After solving the first two or three, they automatically try the solution B-A-2C without searching the problem space for an alternative solution. Take a look at problem 6 again. Although B-A-2C works fine, it entails much more effort than A-C. Yet because of Einstellung, people typically overlook the obvious, easy solution.

Langer (1989) saw that Einstellung effects are one type of mindlessness that characterises human behaviour, particularly in our dealings with other people. All too often we act from a single perspective or rule that has worked in the past. Instead of exploring our environment carefully to seek out alternative courses of action, we sample just enough features to recognise that our set approach seems to be on track.

Einstellung also constrains how we represent problems as well as how we search them.

Self Assessment Questions

- 1) Define problem solving.

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- 2) Describe effective problem solving. What is required for effective problem solving.

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- 3) What are the various other methods of problem solving?

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- 4) What is Einstellung? Explain

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4.3.2 Understanding the Problem

1) **Interpretation**

Develop a relatively clearer understanding of the problem before attempting to solve it.

Devote more time and effort to the initial formulation of ill structured problems.

Look at the immediate problem in its relation to the broader mission and problems of the organisation.

2) **Goals**

Adopt a broader range of goals for problem solving

When solving problems in groups, have less personal stake in any preconceived solution. Because their aim is to arrive at the best solution the group can produce.

4.4 OVERCOMING THE CONSTRAINTS

The problem solver must adequately anticipate many of the constraints likely to arise during problem solving.

They must show a greater tendency to plan, in advance, for how to address anticipated constraints.

They must respond more adaptively and flexibly to constraints that arise unexpectedly.

They should not view the constraints as major impediments to problem solving.

4.4.1 Typical Processes in Solving a Problem

- Think through their solution processes in considerable detail
- Develop an explicit plan for solving the problem, which often includes many steps.
- Collect comprehensive amounts of relevant information from reliable sources as part of developing and implementing their solution plan.
- Monitor progress with the plan and refine it when outcomes are not satisfactory.
- Consult, often extensively, with others in developing their solution plan.
- Plan for follow-up.

4.5 IMPEDIMENTS IN PROBLEM SOLVING

Solving problems is a complex process and each of us is better at the skills required at some stages than others.

A problem exists when an obstacle prevents the person from reaching an objective.

In order to achieve effective problem solving, this problem solving itself can be divided into stages, which must be followed methodically.

Solving problems effectively requires a controlled mixture of analytical and creative thinking.

The following are the list of some of the reasons why people fail to find effective solutions include:

- Not being methodical
- Lack of commitment to solving the problem
- Misinterpreting the problem
- Lack of knowledge of the techniques and processes involved in problem solving
- Inability to use the techniques effectively.
- Using a method inappropriate to the particular problem
- Insufficient or inaccurate information
- Inability to combine analytical and creative thinking
- Failure to ensure effective implementation.

Self Assessment Questions

- 1) What are the two important aspects involved in problem solving?
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- 2) What are the ways in which the constraints in regard to problem solving could be overcome?
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- 3) What are the various impediments in problem solving?
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- 4) Why do people fail to find effective solutions to problems?
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4.6 PRODUCTIVE PROBLEM SOLVING AND IMPEDIMENTS THEREOF

Let us first consider what is required for productive problem solving. The following provides the requirements

A clear description of the problem.

A description of the limiting (or negative) factors involved in the problem.

A description of the constructive (or positive) factors involved in the problem.

A clear delineation of the “ownership” of the problem. Whose problem is it: mine, yours, the other guy’s, my boss’, my spouse’s, my child’s, my parents’, my teacher’s?

A clear description of the scope of the problem: How extensive a problem is it? How long has this problem existed? How many people are affected? What else is affected by this problem?

A clear description of the consequences if the problem were not solved: What is the possible impact on my family, job, marriage, school performance, life in this community, etc., if this problem isn’t solved? What is the worst possible thing that could happen if this problem isn’t solved?

A list of brainstormed solutions to the problem, with each alternative analysed as to its reality, its benefits and the consequences for following each one.

A system of ranking each solution to finalise the decision-making process. A rating system for analysing each solution is developed, e.g., 100 percent chance of success, 75 percent chance of success, 50 percent chance of success.

It is always ideal to brainstorm the problem and to do this one should follow the rules given below:

- 1) Express all ideas.
- 2) Deem no idea too wild to be considered.
- 3) Quantity is important; every idea that comes to mind should be included.
- 4) Getting together with others to brainstorm is desirable.
- 5) Criticism or negative evaluation regarding any idea is forbidden until brainstorming is completed.

Some of the questions one should ask of oneself in order to achieve effective problem solving are:

- Am I procrastinating?
- Am I avoiding the problem?
- Am I in denial?
- Am I shutting down or blocking my creativity on this problem?
- Am I ignoring it, hoping it will go away?
- Am I using magical and/or fantasy thinking in addressing the problem?

4.6.1 Impediments to Productive Problem Solving

- A “Yes, but” attitude.
- Intellectual defensiveness closed to new ideas.
- Fear of being perceived as being incompetent.
- Fear of one’s ideas being unaccepted.
- Inability to be objective about the problem.
- Fear of being wrong.
- Inability to be creative, imaginative or “off the wall” in developing alternative solutions.

Problem Solving

- Being inflexible or too serious to have fun while problem solving.
- Not tuning into one's "inner child".
- Being so chronically immersed or emotionally "stuck" in problems that no feelings or emotions can be elicited.
- Believing that one's emotions and feelings about a problem are "wrong" and should be discounted in problem solving.
- Resentment about having to solve the problem and blaming others for causing the Problem.
- No desire to own up to the problem yourself.
- Believing that problems are the concerns of others, why waste time in trying to solving them.
- Mental and/or physical fatigue from trying to cope with problems and finding no fruitful solutions.
- Burnout, feeling so stressed, anxious or tense in the face of a problem that your body systems shut down.
- Getting so angry about the problem that all energy and attention is drawn to the anger rather than to the problem.
- Feeling sorry for oneself so much that the "self-pity" overwhelms and obstructs all creative thinking on the matter.
- Getting so down or depressed about the problem that it is impossible to come up long enough to deal with the problem.
- Denial that the problem exists.
- Bargaining in dealing with the problem; e.g., agreeing to perform certain steps only as long as the solution to the problem benefits you.

Self Assessment Questions

1) What is meant by Productive problem solving?

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2) What are the essential pre requisites for productive problem solving?

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3) What are the impediments to productive problem solving?

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4) How can you overcome these impediments to productive problem solving?

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4.7 PROBLEM SOLVING IN TEAMS AND SMALL GROUPS

There are many things that make a group or team fail to solve a problem. Some of the barriers in this regard include the following:

1) Lack of structure.

When there is no structure group members lose focus and direction.

2) Poor communication.

This is a barrier that can wreak havoc for every group member that is involved. Poor communication can lead to misunderstanding of the problem. Further poor communication itself can be caused by inattentiveness and dominance that can be made by one or more group members. Ineffective communication will definitely be a negative against any discussion or meeting.

3) No communication

This would be a problem solving killer.

4) Negative attitude

This is a barrier to problem solving in small groups. If members are not flexible and open minded during a discussion or meeting, then a balanced opinion can not be produced.

5) No goal or agenda

When having a team or small group meet for problem solving, it is very important to have a goal or agenda. This in turn will help to avoid most barriers and keep the group focused and organised.

6) Lack of participation

It is important in a small group or team every member should participate in the problem solving process. They must all have clear idea as to what the

group is trying to achieve and give all members time to participate and give their views and feelings. This path, in the end, will help to keep focus, structure, and communication open for all members.

In addition to the above other problems that may affect the problem solving processes are:

- Emotions
- Learning styles
- Gender
- Cognitive barriers
- The lack of transfer of structure between problems.

4.8 CRITICAL THINKING IN PROBLEM SOLVING AND IMPEDIMENTS

Critical thinking consists of three steps:

- 1) Becoming aware that assumptions exist
- 2) Making assumptions explicit
- 3) Assessing their accuracy

Misconceptions about Critical Thinking

- It is a wholly negative process – it tears down ideas and puts nothing in their place
- It will lead to relativistic freeze – the inability to make commitments to people, ideas, and structures.
- It seems to involve traumatic change – one is expected to abandon old assumptions continually.

Other fallacies in regard to problem solving are :

- Irrelevant reason.
- The person's character attached to discredit arguer rather than argument
- Generalisation – one event which follows was cause by first
- Slippery slope with an either or approach which leads to non resolving a problem.
- Appeal to emotion – emotional appeals rather than logical reasons to persuade.

Self Assessment Questions

- 1) How do problems get resolved in teams and groups?

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2) What makes solution to the problem a failure in teams and groups?

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3) What is meant by critical thinking in problem solving?

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4) What are the impediments to problems solving through critical thinking?

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4.9 OTHER BARRIERS TO PROBLEM SOLVING

These are Perceptual blocks, Emotional blocks, Intellectual blocks, Environmental blocks, Culture blocks.

4..9.1 Perceptual Blocks

Perceptual blocks exist when we are unable to clearly perceive a problem or the information needed to solve it effectively .

They include:

a) Seeing *only what you* expect to see

Obscures the “true nature of a problem, either because we exclude relevant information or include information simply because we assume it is there.

b) *Stereotyping*

Often we don't look beyond the obvious and tend to label. For example, if someone isn't working as hard as we would like and we apply the label 'lazy' to that person, we might overlook the possibility that boredom with monotonous work is the problem, and not laziness

c) *Not recognising problems*

Problems go unnoticed until the effects have become severe and emergency action is required.

d) *Not seeing the problem in perspective*

This results from taking too narrow a view of the situation, so that we recognise only part of the problem or the information required to solve it. Sometimes people fail to recognise how different parts of the problem are related, rather they look at the problem more superficially and hence the solution also becomes inadequate.

e) *Mistaking cause and effect*

If cause and effect are confused then we are unlikely to find an effective solution. For example, if goods do not arrive and we assume that the supplier is late in despatching them when in fact our ordering department has failed to send out the order, then our search for solutions will be misdirected. In this situation the late despatch of the goods is an effect of the problem and not a cause.

4.9.2 Emotional Blocks

Emotional blocks exist when we perceive a threat to our emotional needs. These needs differ in type and strength from person to person but include needs for achievement, recognition, order, belonging and self-esteem. The emotional blocks include:

a) *Fear of making mistakes or looking foolish*

This is the most significant emotional block because it affects most of us and is difficult to overcome. As a result of traditional schooling, the expected reaction when we make a mistake or suggest radically different ideas is laughter and ridicule. No one likes being laughed at and as a result we learn to fear making mistakes and to avoid suggesting ideas which are different. This block becomes more severe in the presence of colleagues of a different rank to our own. With those who are more senior we imagine that we will be thought inexperienced or immature. With those more junior we want to protect our image as being knowledgeable and experienced.

b) *Impatience*

Being impatient to solve a problem may be due either to a desire to succeed quickly or to end the discomfort or loss caused by the problem. This has two major consequences. We tend to grab the first solution which comes along, without adequate analysis of the problem, and we evaluate ideas too fast, almost instinctively rejecting unusual ideas. Either way, our solution is unlikely to be the most effective available.

c) *Avoiding anxiety*

This is another common block. Some of us are more susceptible to anxiety and also find it more unpleasant than others. Many factors can cause anxiety, including high risk, disorder and ambiguity, long-term stress, and fear for our security. The effects on problem solving include avoiding risks, indecision in situations which are not 'black and white', excessive reliance on others' judgement, and avoiding challenging the status quo.

d) *Fear of taking risks*

This leads to the avoidance of situations where the outcome is uncertain or could be unpleasant. A major cause is our desire for security. The consequences include setting objectives within easy reach, so that there is no risk of failure, and accepting known solutions in preference to the unusual because their value is certain. A liking for taking risks and over-confidence in being able to avoid unpleasant consequences are more dangerous blocks.

e) *Need for order*

This is related to avoiding anxiety. It can lead to an inability to cope with the frustration of situations which are not clear cut or where ambiguities exist.

f) *Lack of challenge*

This may arise when the problem is routine or the benefits/losses are not significant to us. The result is that either we don't tackle the problem or we take the easiest, quickest route to solution.

4.9.3 Intellectual Blocks

Intellectual blocks exist when we don't have the necessary thinking skills to find a successful solution, or are unable to use them effectively. They include:

a) *Lack of knowledge or skill in the problem solving process*

This is one of the most common blocks. It includes: inadequate skills in analytical and creative thinking; an inflexible strategy, using one approach for every type of problem; the inability to use the various problem solving techniques. They can all lead to ineffective solutions.

b) *Lack of creative thinking*

This is always caused by an inability to use the skills rather than their absence, resulting from the dominance of analytical thinking in our day-to-day lives and a lack of practice.

c) *Inflexible thinking*

This is a difficulty in switching from one type of thinking skill to another, such as from analysis to idea generation or from verbal to visual thinking.

d) *Not being methodical*

This is perhaps the most common block. A step-by-step approach is essential to solving problems effectively.

e) *Lack of knowledge or skill in using the 'Language' of the problem*

If a problem involves a language that we cannot understand or cannot use, such as specialist jargon or statistical analysis, we will not be able to tackle the problem effectively. Similarly, we may use an inappropriate language, such as trying to find an error in accounts by describing the situation verbally rather than analysing it mathematically.

f) *Using inadequate information*

This happens when we do not make sufficient effort to collect the relevant information, or do not understand what information is relevant, where to find it,

or how it relates to the problem. Similarly, using inaccurate information can lead us to the wrong conclusions.

4.9.4 Expressive Blocks

Expressive blocks arise when we are unable to communicate in the way required to produce an effective solution, e.g. not being able to express our ideas effectively to those who have to implement the solution.

Expressive blocks exist when we do not have the knowledge or skills necessary to communicate or record ideas in the ways required. They are caused by an inability to use 'languages' effectively, such as words, drawings, mathematics, scientific symbols, and so on. They include:

a) *Using the wrong language*

Some problems are more effectively solved or communicated using one language rather than another. For example, we are unlikely to get very far if we record data only verbally when the problem requires quantitative analysis. Similarly, people may find it hard to grasp our meaning if we try to explain our feelings about a situation using mathematics instead of words.

b) *Unfamiliarity with a particular application of a language*

The most obvious example is the difficulty many people have making a speech, even though they can write their ideas effectively on paper.

Inadequate explanations

These can result from a real lack of information about what you are trying to convey, or from assuming that your audience already has some of the information when, they don't.

c) *A passive management style*

A situation where we are reluctant to or find it difficult to exert influence may prevent us communicating our ideas effectively. This is particularly important when people need to be convinced of the validity of ideas.

d) *A dominant management style*

This is when we exert oppressive control, either deliberately or unconsciously, and can make those we are communicating with automatically reluctant to accept what we say or hostile to our ideas.

4.9.5 Environmental Blocks

Environmental blocks are caused by external obstacles in the social or physical environment, which prevent us from solving a problem effectively, e.g. distractions from the task.

Environmental blocks, which exist when the social or physical environment hinders our problem solving, include:

i) *Management style*

The way in which we are managed can influence both our attitude to problem solving and the freedom we have to create and implement ideas. For example, if

our ideas are dismissed constantly with comments such as ‘No, it wouldn’t work because ...’, or ‘No, we’ve tried it before and it didn’t work’, we soon give up trying.

ii) *Distractions*

Due to excessive noise and interruptions, these affect some people more than others, but in general they have a detrimental effect on problem solving.

iii) *Physical discomfort*

This can create a distraction as well as resulting in stress or lethargy depending on the circumstances. For example, poorly designed chairs may create a distraction by giving us backache which, in turn, can make us irritable and less interested in any type of work.

iv) *Lack of support*

This comes in many forms. For example, we may need specialist information, advice, skills or other resources, or authority to take action. A more pervasive aspect of this block is a lack of encouragement and the necessary organisational structure to support and exploit people’s ideas.

v) *Stress*

Stress due to pressure of work and deadlines, affects people differently. For those who are susceptible to stress it can be a powerful block, hindering creative thinking in particular.

vi) *Lack of communication*

This has a number of effects, including inability to get the information you require and a lack of encouragement.

vii) *Monotonous work*

This can dull enthusiasm for solving problems and put us onto ‘automatic pilot’, making us blind to problems when they occur.

viii) *Expectations of others*

These can influence both our general performance in problem solving and the objectives we set ourselves. For example, if our peers and superiors are happy with a regular solution to a problem we may feel that it’s a waste of time looking for a new; more effective solution. On the other hand, if we are expected to find an innovative solution we are likely to make a greater effort.

4.9.6 Cultural Blocks

Cultural blocks result from our conditioning to accept what is expected or ‘normal’ in a given situation, e.g. when the work ethic says that we must be serious-minded, but finding an effective solution requires some playful fantasy.

Cultural blocks exist when our problem solving is hindrance by accepting that some things are good or right and are done, while others are bad or wrong and are not done, So that we become bound by custom. They include:

a) *Unquestioning acceptance of the status quo*

There is a tendency to conform to established ideas and methods of working and not to question them or express ideas which depart from them. If something is not normal done we tend to look for the reasons why it can't be done or why it wouldn't work, rather than looking for 'the reasons why it should be done or why it could work'.

b) *Dislike of change*

The attitude that tradition is preferable to change can arise, from the need for security. If a situation is acceptable as it is, any change, which must involve some uncertainty, is felt to be threatening by some people. However, as we become more and more accustomed to change this block is becoming less common, but there must be reasons for change. Change for change's sake can be dangerous.

c) *Fantasy and humour are not productive*

There is still a widespread belief that fantasy and humour have no place in the serious business of problem solving. Subjective reports from innovators suggest otherwise. Fantasy and humour are connected by one common feature – the unlikely combination of ideas (think about it' next time you hear a good joke – the punch line is always unexpected). Innovative solutions to problems arise in the same way – by making a link between apparently unrelated ideas.

d) *Feelings, intuition and subjective judgements are unreliable'*

There is a strong bias towards reason, logic and quantitative judgements because they can be measured and communicated in accurate terms. Feelings, intuition and subjective judgements, which cannot be measured or communicated as effectively, are seen as unreliable and are mistrusted.

Even in mathematics, one of the most logical of sciences, intuition is often reported as playing a key role in, problem solving. A good problem solver needs to be able to use both objective, logical methods and subjective, intuitive methods in the search for solutions.

e) *Over-emphasis on competition or cooperation*

A strongly competitive environment (for recognition, promotion, and so on) can make people unwilling to listen to the ideas of those with whom they are competing. Similarly, in a strongly cooperative environment we may avoid expressing new ideas because we don't want to stand out from the crowd.

f) *Taboos*

Some actions and ideas are excluded from problem solving because they are regarded as distasteful, or are harmful, or contravene accepted moral codes. For example, in a test of creativity a group of students were given a problem to solve using calculus. They had to follow certain rules and the objective was to see who produced the largest number of different routes to the correct solution. A few students produced a lot more than the others because they chose to break the rules they were told to follow.

Although eventually we may not decide to break a taboo, there is no harm in breaking them in thought. This can often lead to new perspectives on a problem.

We can overcome most of our own blocks permanently by re-learning, and overcome other people's blocks which hinder us by learning ways to sidestep them.

Self Assessment Questions

1) What are the various other barriers to problem solving?

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2) What is meant by perceptual blocks to problem solving?

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3) Discuss the emotional and Intellectual blocks in problem solving

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4) Discuss the expressive and environmental blocks in problem solving

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5) What are the cultural blocks that affect problems solving?

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Other barriers

Learning styles: Other barriers to problem solving include Learning styles or how persons learn to solve problems. Some people learn primarily visually, others aurally; some learn step-by-step, others employ an all-or-nothing process; some cogitate on a problem introspectively, while others find they work problems best when they can discuss them.

There is also evidence that some thinking styles that affect the ability to solve problems are gender-linked. For instance it has been found that females organise and relate data more efficiently than males.

Cognitive barriers: to mastering problem-solving is another important factor. The primary difficulty is the inability to identify and use concepts and procedures in analogous but novel situations.

The lack of transfer of structure: between problems is a significant cognitive difficulty, not only for inexperienced problem-solvers but also for experts. Successful transfer rests on the ability to recognise analogies, but even when given an analogy, students often fail to see how to employ it.

A lack of transfer skills: is frequently marked by functional fixedness, the perception that a particular object or concept has only one use. Another problem is superficial transference, where persons identify and link words or variables between problems instead of linking deeper, more meaningful structures.

4.10 TEACHING AND LEARNING STRATEGIES THAT ENHANCE PROBLEM-SOLVING SKILLS

There are two types of strategies that can overcome difficulties in problem-solving:

Pedagogical strategies, which are teacher-centered methods, and Methodological strategies, which tend to be learner-centered.

4.10.1 Pedagogical Strategies

Some pedagogical strategies allow the teacher to address the emotional, psychological, and cognitive barriers to problem-solving simultaneously. For example, on the first day of class, the teacher could have open discussion about the nature of the course material, etc., and encourage students to voice their fears and concerns about it. This approach helps create a comfortable learning environment. Class discussion also reinforces success and transfer of learned skills.

One effective strategy is that active involvement is critical in developing problem-solving skills, and thus student learning groups can be used to promote active experimentation with problems.

Other effective strategies include accepting multiple attempts of solutions for an assignment. The persons should be asked to record how the problem was solved etc., and then discuss if there are other methods that could be used to solve the problem.

Different learning styles as well as gender-specific differences in thinking can be addressed by employing a variety of activities and approaches in teaching.

The traditional instructional mode of lecturing and explaining is effective for only one learning style.

One might use graphics to illustrate concepts, provide opportunities for practice in class, ask for the persons interpretations of data, etc. could also be used to address the other learning styles.

The five steps usually contained in many solution strategies is IDEAL.

- 1) Identify the problem.
- 2) Define and represent the problem.
- 3) Explore possible solution strategies.
- 4) Act on the strategies.
- 5) Look back and evaluate.

This scheme is beneficial in a large number of disciplines.

4.10.2 Promoting Transfer

Other strategies assist persons in transferring problem solving techniques from one problem to very similar or analogous problems.

For successful transfer to occur, it is essential for persons to identify the central theme that is common to a set of problems so they can readily recognise and apply it in more abstract settings.

Through the conscious use of analogy, persons can explore situations which are similar, transferring structure to the problem at hand.

4.10.3 Dialogue

This can also be useful in promoting transfer by highlighting the differences between the problem-solving techniques used by experts and novices. In order to solve a problem, both experts and novices do follow the same pattern, that is, they read and analyse, plan a strategy, act on that strategy to produce a solution, and then try to verify it.

Encouraging people to talk through the differences between problems that have similar superficial structures but different deep structures decreases the risk of incorrect transfer.

Having students work on numerous problems individually and in groups also facilitates transfer.

Choosing problems which evolve from simple and well-defined to complex and ill-defined will help people to develop transfer skills.

To develop better problem-solvers, persons should be helped to overcome both emotional and cognitive barriers to learning effective problem-solving skills.

By first creating a comfortable environment and helping people to overcome their fears and anxieties related to problem-solving, one lays the necessary foundation for successful learning.

Then using an array of pedagogical and methodological strategies, one can promote in the person the ability to reflect on the problem-solving process itself and provide critical tools for and practice in productive problem-solving.

Self Assessment Questions

- 1) Discuss the other barriers related to the person that affect the problem solving adversely.

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- 2) What is IDEAL. Elaborate. How do these help in problem solving?

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- 3) Discuss the pedagogical strategies in problem solving.

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- 4) Explain how promoting transfer and dialogue help in problem solving?

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4.11 FUNCTIONAL FIXEDNESS

Functional fixedness discovered by Duncker (1935) refers to the tendency to see objects as having only a single, typical use. A hammer is for pounding nails and other things for instance. We categorise objects based on their functional features as well as their features. Generally the prototypical function dominates the way we think.

Dunker in his experiment led an individual into a room with a table holding several small objects. They included three cardboard boxes filled with candles, tacks and matches, respectively and an ashtray, paper, paper clips, string, pencils, and tinfoil. The individual was instructed to mount the candles at eye level on the wall, ostensibly to prepare the room for a vision experiment. Can you think of a way to put the candles on the wall using these materials?

Dunker found that only 43% of his participants could develop a solution to the problem. He hypothesised that they fixated on the common function of a box, namely, to serve as a container.

To help break their functional fixedness, he repeated the experiment but this time emptied the candles, tacks, and matches on the table, leaving the boxes empty. Under these circumstances, all participants solved the problem by first mounting the boxes on the wall using the tacks, which then served as platforms for the candles.

Here is another example of functional fixedness, called the *coin problem* (Simmel, 1953). Suppose you have eight coins and a balance. One of the coins is a counterfeit coin and therefore lighter than the others. The problem is to find the counterfeit coin by using the balance only twice?

Most people initially think of dividing the coins into two groups of four coins each. One of the groups of four will be lighter and so must contain the counterfeit coin. Then you can take the four coins from that group, and weigh them two against two. Of course, one of the groups of two will be lighter. However, you cannot determine which of the two remaining coins is counterfeit, because you have already used the balance twice.

Before we consider how to approach this problem correctly, let us analyse the previous solution attempt. Why do we initially divide the coins into two groups of four? One reason is that we know that eight things can be evenly divided into two groups of four. One of the functions of the number eight is that it can be so divided.

The fact that $4 + 4 = 8$ is a highly available bit of knowledge for us. Because this property of the number eight is so available, it is the first thing we think of. In fact, when people try to solve this problem, they often keep coming back to the four versus four divisions. When the obvious way of using things keeps us from seeing the correct way of using them, then we are functionally fixed.

In Simmel's coin problem, the solution is often very difficult to see. You need to divide the coins in a way that is far from obvious at first. Suppose you divide them into three groups of three, three and two coins. Then weigh three versus three. If they balance, then the counterfeit coin must be in 'the group of two coins. Your second weighing, then, is to take the group of two coins, and weigh one versus one. Alternatively, suppose on your first weighing one group of three coins is lighter: Then on your second weighing, take any two of the three coins and weigh one against the other. If they balance, then the third (unweighed) coin must be the counterfeit one. If they do not balance, then lighter one is counterfeit. This procedure is guaranteed to find the solution. However, it is much more complex and unfamiliar than the wrong procedure.

Thus, finding solutions to problems may require you to overcome functional fixedness. It may only be after you have realised that the obvious ways of tackling a problem do not work that you will be open to a reorganisation of the problem that will allow you to see the solution.

4.12 USING INCOMPLETE OR INCORRECT REPRESENTATIONS

A related difficulty in problem solving has to do with initial interpretation of the problem. If the information is misunderstood, or if the wrong information is provided/ focused upon, the solver is at a disadvantage. This can be illustrated by a problem from Perkins (1981):

“There is a man at home. That man is wearing a mask. There is a man coming a home. What’s happening?”

Most of the people start to go wrong in making assumptions about the home in situation. Many equate home with house, although the answer is baseball game. Perkins (1981) argue that assumptions people make in interpreting the problem are a kind of mental set and that this mental set hinders problem solving.

In terms of representation, representing the problem in terms of a person sitting in a house would lead you down the wrong path. It would be a case of using an incorrect representation, that is one that included information not presented in the problem and not correct.

The choice of representation can often make a great difference. Schwartz (1971), studying problems such as this one found that people who constructed charts and flow charts were successful in solving the problems than people who merely wrote down available facts.

Here’s another example of a case where representation can make a problem either very easy or very hard. It is called the numbers game and the objective of each player is to choose from the set of digits enough to make an exact total of fifteen from three digits.

Two players are given a sheet of numbers, 1 2 3 4 5 6 7 8 9.

They take turns crossing one of the digits off the list and adding it to their own list.

The first player to have three digits totaling 15 (for example 4, 5, 6; or 1, 6, 8) wins.

If you were to play this game, what would your problem solving strategy be? What if you played first, which digits would you choose? What if you played second and your opponent had first chosen a five?

The first time or two if you play this game, you might find it surprisingly challenging. Now look at the figure below and notice how this problem can be represented alternatively:

6	7	2
1	5	9
8	3	4

Notice that, depicted this way, the difficult numbers game is actually the game of tic tac toe in disguise. Represented this way the game is easy but without this representation the problem is much harder to solve.

Self Assessment Questions

- 1) What is Functional Fixedness? Explain mental set in problem solving.

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- 2) Present Duncker's experiment.

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- 3) How does coin problem demonstrate functional fixedness?

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- 4) What is meant by incomplete or incorrect representations? How do these affect problem solving? Give suitable examples

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4.13 LACK OF PROBLEM SPECIFIC KNOWLEDGE OR EXPERTISE

Until now we have been discussing general problem solving abilities with problems that have a puzzle like character. The assumption is that most of these problems are about equally unfamiliar to everyone and that people basically go about solving them in the same way. Other kinds of problems – for example,

those in chess or others killed games; textbook problems in physics, geometry, or electronic; computer programming and problems in diagnoses and management of health problems – seem to be different kind from the puzzles we have been talking about. In particular, experts and novices approach most such problems differently (Chi, Glaser & Farr, 1988).

Familiarity with a domain of knowledge seems to change the way one solves problems within a frame of reference. A good example is to compare the ability to of undergraduate psychology students from their professors in designing experiments.

A classic study of expert novice differences was carried out by de Groot (1965). He examined the thinking process of both chess masters and weaker players considered about the same number of possibilities but somehow chose the best move more easily. Chase and Simon (1973), in a replication study, found that the more expertise a chess player had, the more information he extracted even from brief exposures to chess boards set up to reflect ongoing chess games. That is, when a chess master and chess beginner are both shown a chess board for five seconds, the chess master will remember more about where the pieces were placed, but only if the pieces are configured to depict a chess game.

In problem solving, experts see and represent a problem in their domain at a deeper and more principled level than do novices, who tend to represent information superficially (Chi, Feltovich, & Glaser 1981). For example, when solving physics problems experts tend to organise the problems in terms of physics principles like Newton's first law of motion; novices instead tend to focus on the objects mentioned in the problem, such as an inclined plane or a frictionless surface. Experts tend to spend proportionately more time qualitatively analysing the problem, trying to grasp or understand it; relative to novices who are more likely to plunge in and start looking at solutions. Finally, throughout the process of problem solving, experts are more likely to check for errors in their thinking.

Expertise by itself is not always enough for problem solving other factors like medical status, mental status and other related aspects can also affect problem solving abilities (Goel & Grafman, 2000).

4.14 LET US SUM UP

As discussed in earlier chapters problem solving involves both domain specific and general strategies that people may use and may be attained through various techniques. However, most of us often come across many situations when our attempts at problem solving fail. This is largely because there are numerous factors that are influential impediments to problem solving. Einstellung (or set or mental set) and functional fixedness are classic obstacles to both proper representation and search identified by the gestalt psychologists. Einstellung is the tendency to set the mind into a routine approach to problem solving. Functional fixedness refers to the tendency to see objects as having only a single, typical use. Researchers have also talked about the novice versus expert differences in problem solving.

4.15 UNIT END QUESTIONS

- 1) What is a mental set? Think of the few problem situations where you think your mental set hampered effective problem solving.
- 2) Describe some novice expert differences in problem solving.
- 3) Critically evaluate the concept of functional fixedness.
- 4) Compare and contrast with the help of examples the concept of Einstellung with the concept of functional fixedness.
- 5) How does lack of problem specific knowledge or experience affect problem solving?

4.16 SUGGESTED READINGS

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